

Comparative evaluation of antimicrobial potential of garlic and ginger extracts against Streptococcus mutans and Lactobacillus acidophilus: An in-vitro study¹Dr. Anshu Alam, MDS, Department of Public Health Dentistry, BIDSHP, Patna, Bihar.²Dr. Shobha Rani, MDS, Department of Public Health Dentistry, BIDSHP, Patna, Bihar.³Dr. Kumari Sony, MDS, Department of Public Health Dentistry, Dental officer, CHC Jainagar, Koderma, Jharkhand**Corresponding Author:** Dr. Anshu Alam, MDS, Department of Public Health Dentistry, BIDSHP, Patna, Bihar.**Citation of this Article:** Dr. Anshu Alam, Dr. Shobha Rani, Dr. Kumari Sony, “Comparative evaluation of antimicrobial potential of garlic and ginger extracts against Streptococcus mutans and Lactobacillus acidophilus: An in-vitro study”, IJDSIR- January – 2025, Volume – 8, Issue – 1, P. No. 126 – 137.**Copyright:** © 2025, Dr. Anshu Alam, et al. This is an open access journal and article distributed under the terms of the creative common’s attribution non-commercial License. Which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given, and the new creations are licensed under the identical terms.**Type of Publication:** Original Research Article**Conflicts of Interest:** Nil**Abstract****Background:** Garlic and Ginger belong to the plant family Liliaceae. Streptococcus mutans is believed to be the chief etiologic agent in dental caries, while lactobacillus acidophilus causes carious lesions to progress. Chlorhexidine is the “gold-standard” in decreasing the oral microbial counts with side effects like brown discoloration of the teeth and undesirable taste. Thus, there is a need for an alternative, cost-effective biologic product for oral diseases.**Aim:** To comparatively evaluate the antimicrobial potential of Ginger and Garlic extracts against Streptococcus mutans (S. mutans) and Lactobacillus acidophilus (L. acidophilus).**Objectives:** - To determine the antimicrobial efficacy of Ginger and Garlic extracts against cariogenic bacteria (Streptococcus mutans and Lactobacillus acidophilus) at varying volumes (5µl, 10µl, 15µl, and 20µl), and to

compare their antimicrobial effects with 0.2% Chlorhexidine (CHX) at different volumes.

Materials and methods: Ethanolic extracts (10% each) of ginger and garlic were prepared and subjected to microbiological assay along with 0.2% chlorhexidine gluconate (CHX) as a control group, to determine its zone of inhibition at volumes of 5µl, 10µl, 15µl and 20µl using Agar disk diffusion test against Streptococcus mutans and Lactobacillus acidophilus. One-way ANOVA test was applied to compare the difference between two groups using statistical analysis software SPSS version 21.0. Statistical significance was set at $p \leq 0.05$.**Results:** The diameter of zone of inhibition for garlic extract ranged from 11.49±0.05 mm to 37.83±0.05 mm while for ginger extract it ranged from 7.38±0.03 mm to 22.53±0.13 mm at various volumes used. The maximum antimicrobial activity was exhibited by 0.2% Chlorhexidine (30.30±0.05mm) followed by 10%

ethanolic garlic extract (37.83 ± 0.05 mm) and least by 10% ethanolic extracts of ginger (22.53 ± 0.13 mm) against Streptococcus mutans at all volumes except the highest volume of 20 μ l (33.51 ± 0.29 mm). While the maximum antimicrobial activity was shown by 10% ethanolic extract of garlic (45.40 ± 0.03 mm) followed by 10% ginger extract (38.24 ± 0.06 mm) and least by 0.2% Chlorhexidine (18.72 ± 0.07 mm) at all volumes when the comparison of the extracts was done against Lactobacillus acidophilus.

Conclusion: These results suggest that garlic has greater antimicrobial efficacy against Streptococcus mutans and Lactobacillus acidophilus and also, it raises the possibility that it can be used as an alternative antibacterial compound in the reduction of dental caries and other oral infections.

Keywords: Antimicrobial Activity, Garlic, Ginger, Streptococcus Mutans, Lactobacillus Acidophilus.

Introduction

The proverbial expression “variety is the very spice of life, that gives it all its flavor” -William Cowper holds true in every aspect of life, including nutrition. Herbs and spices can serve as a powerful tool to diversify an individual’s plate and palate. These have been important to mankind since the beginning of history as they are mentioned in the Epic of Gilgamesh, the Bhagavad Gita, and the Old Testament. Throughout the world, herbs and spices have been an integral part of culinary culture and have a long history of use for flavoring, coloring, and preserving food, as well as for medicinal purposes [1].

Evidence for the use of plants for medicinal purposes dates 60,000 years back in both Western and Eastern cultures; in both developed and undeveloped countries. The WHO (2018) estimated that about 65% of the world’s population are mainly relying on natural

products derived from plants for their primary health care systems and most of them are from developing countries, the remaining 35% are mostly from developed countries who also used natural products indirectly to maintain a good health [2]. Most of the plants used for medicinal and dental purposes have been identified and their applications are well documented and described by different authors. Some common herbs such as ginger and garlic have been used since ancient times as antimicrobial agents and offer great health benefits by virtue of their powerful phytochemical and antioxidant properties. Therefore, there has been a change in thinking globally, with a growing tendency to “Go Natural”[3].

Allium sativum

Garlic is a perennial herb consisting of narrow flat leaves with height of 20-40 cm that belongs to the genus Allium and is confined all sides by membranous patches [4,5]. Being a natural health promoter, this pungent wonder of nature is botanically known as Allium sativum and is a member of Alliaceae or Liliaceae family. Due to its strong odoriferous nature, garlic is commonly known as stinking rose [6].

Table 1: Synonyms of Garlic

<i>Poor Man’s Treacle</i>
<i>Star of envy</i>
<i>Stinking Rose</i>
<i>The Bulb of the Tree of Life</i>
<i>The Fragrant Pear</i>

Table 2: Botanical Classification of Garlic

KINGDOM	PLANTAE
Order	Asparagales
Family	Amaryllidaceae
Subfamily	Allioideae
Genus	Allium
Species	A. Sativum

The word garlic is derived from the old English word **garleac** i.e. spear leek. The ‘**gar**’ means spear or lance in Old English (referring to spear shaped leaves) and ‘**leac**’ means leek or protherb or vegetable. The origin of garlic dates back from 5000 to 6000 years. It is a native to Central Asia, but it is difficult to trace the country of its origin [6, 7]. There is some evidence that during the earliest Olympics in Greece, garlic was fed to the athletes for increasing stamina (Lawson et al; 1998) [8]. It has also been used as a home-based prophylactic and symptom management agent in the recent COVID-19 emergence, it was reported to have therapeutic efficacy against multiple symptoms observed in advanced COVID-19 patients. In India, it is used in various forms like garlic powder, garlic oil or whole garlic. This has gained it the title of **super food** [6]. Results from different studies have shown that garlic extracts have the capacity to inhibit the growth of some pathogenic microorganisms. Their antimicrobial activity has been linked to the presence of sulfur compounds, specifically, allicin which is produced by the enzyme alliinase after crushing or bruising a garlic bulb. Allicin produces diallyl sulfide, the most important volatile compound of garlic and gives it its characteristic smell [9].

“Garlic has established a reputation as an all-healing herb”

Zingiber officinale

Ginger is another recognized spice, which derived its name from the genus Zingiber, and the family Zingiberaceae and is largely utilized as herbal medicine in Australia, Asia, Europe, America and Africa [10]. Other names of ginger are **African ginger, Black ginger, Cochin ginger, jengibre, Ingwer, Jamaican ginger and Race ginger**. The English botanist William Roscoe (1753-1831), gave the plant the name Zingiber, derived from a Sanskrit word singabera which means horn-shaped due to the protrusions on the rhizome (Katzner, 1999) [11].

Ginger is a horizontal, branched, fleshy, aromatic white to yellow colored perennial rhizomatous herb reaching up to 90 cm long. The stem sticks up about 12 inches above ground and is surrounded by the sheathing bases of the two-ranked leaves. It creates sets of flower sprouts (pink and white) that develop into yellow flowers. As a result of the beautiful appearance and the habituation of plant to hot weather, it is usually utilized as a scenery across sub-equatorial homes [12].

In the book **Herbal Medicine by Ann M. Bode and Zigang Dong: Biomolecular and Clinical Aspects**, ginger plays an important role in inhibiting several diseases such as arthritis, cramps, rheumatism, sprains, sore throats, muscular aches, hypertension, indigestion, dementia, fever and many more. In addition, it has been proven to have incredible antimicrobial activity due to the components of volatile sesquiterpene hydrocarbons (zingiberene and bisabolene), mono-terpenoids (curcumene and citral) and phenolic compounds

(shogaol, paradol and gingerol) which are fat-soluble phenols isolated from ginger rhizome [13].

Dental caries is one of the most common infections of all oral diseases. Of all the bacterial species, *Streptococcus mutans* (SM) has been reported as the principal etiologic agent for dental caries, while, *Lactobacillus acidophilus* (LA) characteristically cause existing carious lesions to progress, especially coronal caries [14]. Of all the commonly used mouthwashes, Chlorhexidine (CHX) digluconate has a long history as an effective antimicrobial agent in inhibiting the formation of dental plaque. CHX is considered as a “gold-standard” in decreasing the counts of oral microbial counts. In many studies, it is considered as a positive control group to compare its effect with that of other materials. However, despite all its advantages, it has some disadvantages, including, change in taste perception, tooth discoloration, oral mucosal erosion, burning sensation and xerostomia [15]. Thus, there is a need for an alternative, safe, efficacious and cost-effective treatment options for the prevention of oral diseases.

Considering the high prevalence of caries in different communities, its prevention is one of the research priorities. Therefore, with the above background, the present study was undertaken to comparatively evaluate the antimicrobial activity (in vitro) of garlic and ginger extracts against the most common oral pathogens *Streptococcus mutans* and *Lactobacillus acidophilus*.

Materials & Methods

This in-vitro study was conducted at the Department of Microbiology between August and October 2023, subsequent to obtaining ethical clearance and approval from the Institutional Ethical Committee.

Collection of plant materials

Fresh ginger and garlic were procured from local markets in Patna. To ensure cleanliness, they were

thoroughly washed with tap water to remove any dirt. This was followed by a final rinse with distilled water to eliminate any remaining impurities. The cleaned ginger and garlic were then air-dried in shade at room temperature to prevent any moisture-related spoilage. Finally, they were stored in separate mesh bags at a refrigerated temperature of 4°C to maintain their freshness and potency.

Saliva collection

Five subjects were randomly recruited for this in vitro study, after obtaining their written informed consent. Unstimulated whole saliva samples were aseptically collected using sterile cotton swabs, which were then immediately stored in sterile swab tubes.

Preparation of culture media

For the isolation of *Streptococcus mutans* and *Lactobacillus acidophilus*, Mitis Salivarius Bacitracin Agar (MSB Agar) and Rogosa Selective Lactobacilli Agar (RSL Agar) were employed as selective culture media, respectively. The isolated bacteria were subsequently sub-cultured under stringent aseptic conditions.

Preparation of standard inoculum

For the isolation of pure culture of *S. mutans* and *L. acidophilus*, the collected saliva samples were inoculated into selective media, Mitis Salivarius Bacitracin Agar (MSB Agar) for *S. mutans* and Rogosa Selective Lactobacilli Agar (RSL Agar) for *L. acidophilus*. The inoculated media were then anaerobically incubated at 37°C for 48 hours to obtain pure cultures.

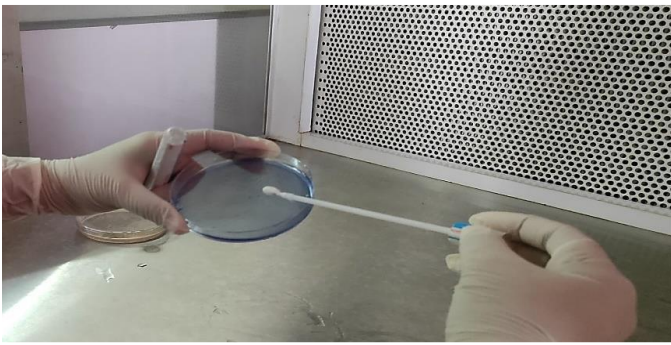


Fig. 1: Shows the inoculation of saliva sample in petri plate containing Rogosa Agar

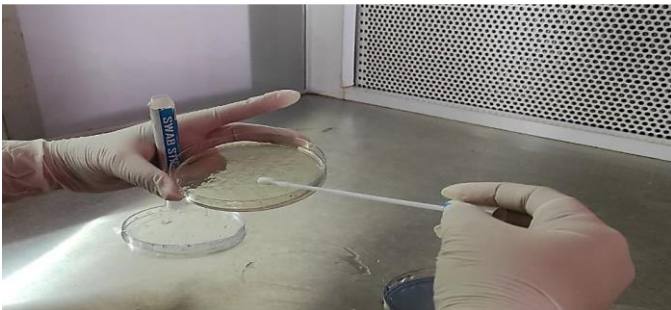


Fig. 2: Shows the inoculation of saliva sample in petri plate containing Mitis Agar

Preparation of ethanolic extracts

500 grams each of fresh ginger and garlic were prepared for extraction. Initially, the samples were cleaned, peeled, sliced, and dried at room temperature. The dried samples were then powdered and mixed with 1000ml of 70% ethanol in separate containers. The mixture underwent cold maceration for 48 hours, during which it was subjected to continuous shaking at regular intervals. Following maceration, the mixture was filtered using a sterile 0.45µm Millipore filter to separate the residue from the filtrate. The filtrate and residue were then dried at a low temperature (<60°C) for 3 days to facilitate evaporation of the ethanol content. After 3 days of obtained solid residue, they were crushed into a homogenous paste using a mortar and pestle. The resulting extracts were then stored in sterile, airtight containers and refrigerated at 4°C until further use. A 0.2% Chlorhexidine gluconate mouthwash was used as a control in the study.

Preparation of 10% ethanolic extracts

The 10% stock solution of ethanolic extracts was prepared by dissolving 10gm of the obtained extracts in 90ml of Dimethyl Sulfoxide (DMSO), resulting in a homogeneous 10% (w/v) solution of the ethanolic extracts.

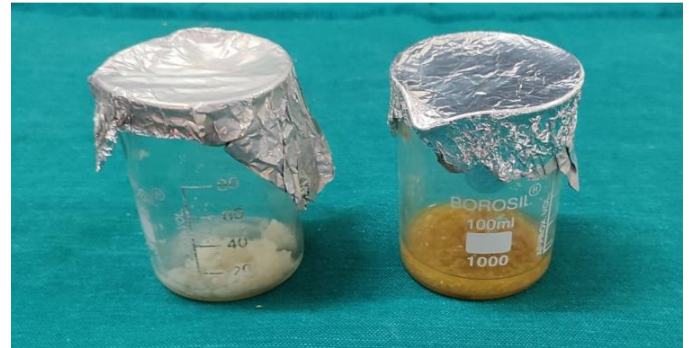


Fig. 3: Shows obtained extracts of garlic and ginger

Procedures for determination of antimicrobial activity of 10% ethanolic extracts against *S. mutans* and *L. acidophilus*

Mitis Salivarius Bacitracin Agar (MSB Agar) and Rogosa Selective Lactobacilli Agar (RSL Agar) plates were prepared and sterilized. Saliva sample was inoculated onto the plates using a sterile cotton swab and allowed to cool and solidify at room temperature. After 15-20 minutes of drying, the plates were ready for antimicrobial testing. The 10% ethanolic extracts of garlic and ginger were evaluated for antibacterial activity using the disc diffusion method. This assay assessed the inhibitory effects of the extracts on the growth of microorganisms present in the saliva sample, providing valuable insights into their antimicrobial properties.

Disc diffusion method

Four sterile discs, each measuring 3mm in diameter, were placed on MSB Agar and RSL Agar-containing petri dishes and gently pressed to ensure complete contact with the media surface. Varying volumes (5µl, 10µl, 15µl and 20µl) of garlic and ginger extracts, along with a control, were added to separate discs and spread

evenly. The culture plates were incubated aerobically at 37°C for 24-48 hours.

After incubation, the plates were examined for clear zones around the discs, indicating inhibition of microbial growth. The antimicrobial activities of the extracts against the test isolates were quantified by measuring the diameters of the zone of inhibition (areas without test organism growth) to the nearest millimeter using a sterilized electronic Vernier Caliper.

Statistical Analysis

The data obtained from this study were subjected to statistical analysis using the Statistical Package for Social Sciences (SPSS) software, version 21.0. The results were expressed as mean values \pm standard deviation. To determine significant differences, a one-way analysis of variance (ANOVA) was employed for comparison of means. The level of statistical significance was set at $p \leq 0.05$ for all tests, indicating that any observed differences were statistically significant if the p-value was less than or equal to 0.05.

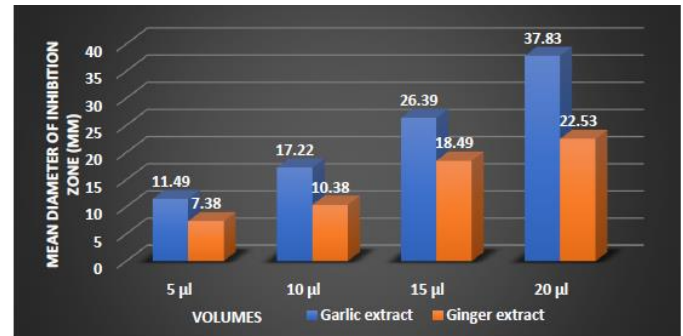
Results

The antimicrobial potential of garlic and ginger extract against *S. mutans* and *L. acidophilus* was determined by disc diffusion method at various volumes (5 μ l, 10 μ l, 15 μ l and 20 μ l) in comparison with 0.2% Chlorhexidine gluconate as the positive control. The data obtained from the study were tabulated and subjected to statistical analysis.

The present study revealed that garlic extract exhibited a significantly greater inhibitory effect against *Streptococcus mutans* compared to ginger extract at various volumes (5 μ l, 10 μ l, 15 μ l, and 20 μ l). The zone of inhibition for garlic extract ranged from 11.49 \pm 0.05 mm to 37.83 \pm 0.05 mm, whereas for ginger extract, it ranged from 7.38 \pm 0.03 mm to 22.53 \pm 0.13 mm. Statistical analysis revealed a significant difference ($p=0.0001$) in

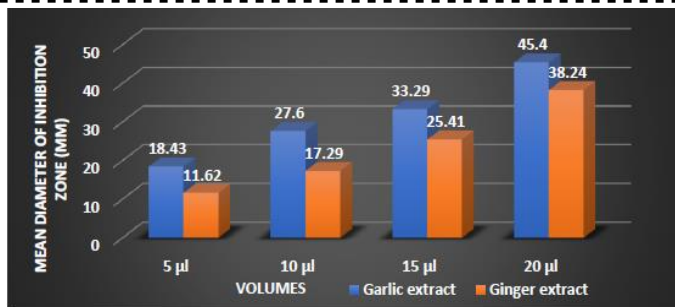
the zones of inhibition between garlic and ginger extracts at varying volumes, indicating a dose-dependent antibacterial response. These findings suggest that garlic extract possesses potent antibacterial activity against *S. mutans*, surpassing that of ginger extract. (Graph 1)

Graph 1: Shows the comparison of mean zone of inhibition (mm) at various volumes (μ l) of Garlic and Ginger extract against *Streptococcus mutans*.



Graph 2 shows that garlic extract exhibited a significantly greater inhibitory effect against *Lactobacillus acidophilus* compared to ginger extract at various volumes (5-20 μ l). The zone of inhibition for garlic extract ranged from 18.43 \pm 0.03 mm to 45.40 \pm 0.03 mm, surpassing that of ginger extract (11.62 \pm 0.03 mm to 38.24 \pm 0.06 mm). Statistical analysis revealed a significant difference ($p=0.0001$) in the zones of inhibition between garlic and ginger extracts at varying volumes, indicating a dose-dependent antibacterial response. These findings suggest that garlic extract possesses potent antibacterial activity against *L. acidophilus*, outperforming ginger extract at all volumes tested.

Graph 2: Shows the comparison of mean zone of inhibition (mm) at various volumes (μ l) of Garlic and Ginger extract against *Lactobacillus acidophilus*



The present study revealed that 0.2% Chlorhexidine gluconate exhibited the highest zone of inhibition against *Streptococcus mutans* at volumes of 5-15µl, followed by garlic and ginger extracts. However, at the maximum volume of 20µl, garlic extract surpassed chlorhexidine, demonstrating the highest zone of inhibition. The study also observed a dose-dependent increase in the zone of inhibition with increasing volumes of the extracts. Statistical analysis using Analysis of Variance (ANOVA) confirmed significant differences (p=0.001) in antimicrobial effects between and within the groups. (Table 1).

Table 1: Shows the comparison of mean zone of inhibition (mm) at various volumes (µl) of Garlic and Ginger extracts with 0.2% Chlorhexidine gluconate against *Streptococcus mutans*

Inhibition zone diameters (mm)	<i>Streptococcus mutans</i>				ANOVA (p-value)
	5µl	10µl	15µl	20µl	
Ginger	7.38±0.03	10.38±0.16	18.49±0.05	22.53±0.13	0.001 (S)
Garlic	11.49±0.05	17.22±0.05	26.39±0.22	37.83±0.05	0.001 (S)
Chlorhexidine	22.37±0.06	27.60±0.04	30.30±0.05	33.51±0.29	0.001 (S)
ANOVA (p-value)	0.001	0.001	0.001	0.001	

* p<0.05 statistically significant, ANOVA= Analysis of Variance, S= significant .

Table 2 demonstrated that garlic extract exhibited the highest mean zone of inhibition against *Lactobacillus acidophilus*, followed by ginger extract, and then 0.2% Chlorhexidine gluconate. A dose-dependent increase in the zone of inhibition was observed with increasing volumes of the extracts. Statistical analysis using one-

way ANOVA revealed a statistically significant difference (p=0.001) in antimicrobial effects between and within the groups, indicating the superior efficacy of garlic extract against *L. acidophilus*.

Table 2: Shows the comparison of mean zone of inhibition (mm) at various volumes (µl) of Garlic and Ginger extracts with 0.2% Chlorhexidine gluconate against *Lactobacillus acidophilus*.

Inhibition zone diameters (mm)	<i>Lactobacillus acidophilus</i>				ANOVA (p-value)
	5µl	10µl	15µl	20µl	
Ginger	11.62±0.03	17.29±0.05	25.41±0.04	38.24±0.06	0.001 (S)
Garlic	18.43±0.03	27.60±0.06	33.29±0.05	45.40±0.03	0.001 (S)
Chlorhexidine	8.52±0.05	13.32±0.07	15.62±0.09	18.72±0.07	0.001 (S)
ANOVA (p-value)	0.001	0.001	0.001	0.001	

* p<0.05 statistically significant, ANOVA= Analysis of Variance, S= significant

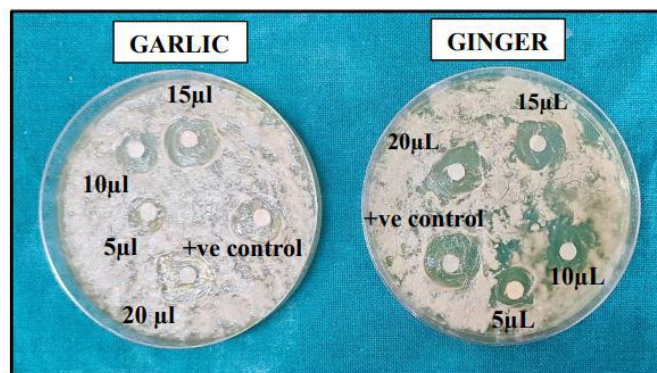


Fig. 4: Shows clear zone of inhibition formed by 10% ethanolic extract of Garlic and Ginger at various volumes against *Streptococcus mutans*.



Fig. 5: Shows clear zone of inhibition formed by 10% ethanolic extract of Garlic and Ginger at various volumes against *Lactobacillus acidophilus*.

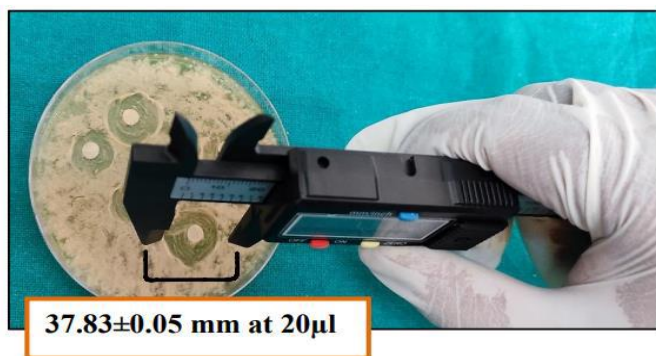


Fig. 6. Shows the measurement of zone of inhibition formed by 10% ethanolic extract of Garlic against *Streptococcus mutans* with the help of Vernier Caliper.

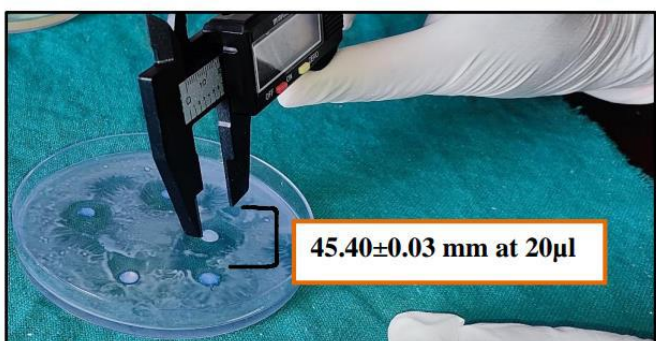


Fig. 7. Shows the measurement of zone of inhibition formed by 10% ethanolic extract of Garlic against *Lactobacillus acidophilus* with the help of Vernier Caliper.

Discussion

Nature has bestowed our country with an enormous wealth of medicinal plants; therefore, India has often been referred to as the Medicinal Garden of the world [16,17]. Medicinal plants and spices are one of the most commonly used natural antimicrobial agents in foods and have been used traditionally for thousands of years by many cultures in the control of common health complications [18]. Also, these continue to be an important therapeutic aid for alleviating the ailments of humankind [17,19].

The World Health Organization (WHO) reported that almost 80% of people are using traditional medicine based on plant-based medications. Ginger and garlic are

of particular interest to scientists for ages and are gaining popularity due to their antimicrobial activities. This revival of interest in plant-derived drugs is mainly due to the current widespread belief that “green medicine” is safe and more dependable than the costly synthetic drugs, many of which have adverse effects [19].

In the past four decades, microbial ecologists including microbiologists, taxonomists, molecular biologists, biochemists, epidemiologists, and dental scientists have accumulated information which has led to the identification of the presumed pathogens of dental caries and periodontal diseases. So, in order to prevent dental diseases, it is important to decrease the bacterial load of plaque [14].

Currently, Chlorhexidine gluconate (CHX) is the most potent chemotherapeutic agent against dental caries but due to its various side effects, it discourages patient to use it as a mouthwash. The use of natural products such as ginger and garlic could be considered as a potential source of novel antimicrobial agents, used extensively for the treatment of cold, nausea, diarrhea and dental infections [20]. *Streptococcus mutans*, *Lactobacillus*, *Actinomyces* spp. and some other anaerobic bacteria are considered to be the primary cariogenic agents involved in the development of dental caries. Because of the increased bacterial resistance to antibiotics, toxic and harmful effects of few common antibacterial agents, there is a continuous need for alternative therapies which are affordable, non-toxic and cost-effective, such as plants [14]. Hence, the purpose for this research was to compare and evaluate antimicrobial efficacy of 10% ethanolic extracts of ginger and garlic each with 0.2% CHX (positive control) against *Streptococcus mutans* and *Lactobacillus acidophilus* at various volumes (5 μl , 10 μl , 15 μl and 20 μl) using agar disk diffusion test.

The current study revealed that 10% ethanolic garlic extract exhibited a significantly wider zone of inhibition compared to 10% ethanolic ginger extract against both *Streptococcus mutans* and *Lactobacillus acidophilus*. The zone of inhibition for 10% ethanolic garlic extracts against *Streptococcus mutans* ranged from 11.49 ± 0.05 mm to 37.83 ± 0.05 mm, whereas 10% ethanolic ginger extract showed a range of 7.38 ± 0.03 mm to 22.53 ± 0.13 mm. This finding contradicts a study by Asimi OA et al., [21] which reported similar antimicrobial activity between garlic and ginger extracts. The antimicrobial potency of garlic is primarily attributed to allicin, a sulfur-containing compound that inhibits bacterial growth by disrupting DNA and protein synthesis, as well as RNA synthesis. Additionally, phenolic, organosulfur compounds, amino acids, carboxylic groups, and proteins contribute to garlic's antibacterial activity.

The present study demonstrated that 0.2% Chlorhexidine exhibited maximum antimicrobial activity (30.30 ± 0.05 mm) against *Streptococcus mutans*, followed by 10% ethanolic garlic extract (37.83 ± 0.05 mm at $15 \mu\text{l}$ and 33.51 ± 0.29 mm at $20 \mu\text{l}$) and 10% ethanolic ginger extract (22.53 ± 0.13 mm). Notably, garlic extract surpassed Chlorhexidine at the highest volume of $20 \mu\text{l}$. Statistical analysis revealed a significant difference ($p=0.001$) in antimicrobial effects, confirming Chlorhexidine's efficacy in preventing *Streptococcus mutans* growth. Although less potent than Chlorhexidine, garlic and ginger extracts showed relatively effective inhibition against oral bacteria. The superior antimicrobial activity of Chlorhexidine can be attributed to its bis-guanide structure and cationic nature, facilitating adsorption to tooth surfaces. These findings are consistent with Priti Yadav et al.'s [20] study, which reported similar zone of inhibition values for Chlorhexidine, garlic, and ginger extracts. However, this

result contrasts with studies by Kshirsagar et al [7] and Mansour Amin et al., [22] which reported garlic extract's superior antimicrobial activity over Chlorhexidine.

The present study underscores the superior antimicrobial efficacy of garlic extract compared to ginger extract against *Lactobacillus acidophilus*. The findings revealed a significant and dose-dependent increase in the zone of inhibition for garlic extract, ranging from 18.43 ± 0.03 mm to 45.40 ± 0.03 mm, whereas ginger extract exhibited a relatively lower antimicrobial activity, with a range of 11.62 ± 0.03 mm to 38.24 ± 0.06 mm. Statistical analysis confirmed highly significant differences ($p = 0.0001$) between the two extracts at all volumes, emphasizing the potent antimicrobial properties of garlic extract. These results align with previous studies, which attribute garlic's antimicrobial effects to its active compounds, particularly allicin. The implications of this study are twofold. Firstly, garlic extract's superior antimicrobial efficacy suggests its potential as a natural agent for preventing or treating *L. acidophilus*-related infections. Secondly, the study's findings contribute to the growing body of evidence highlighting the antimicrobial properties of plant-based compounds, which may offer alternative solutions to conventional antimicrobial therapies. This finding is in line with the study conducted by Kshirsagar et al [7] and Houshmand B et al [22] who reported more inhibitory effect of garlic on *Lactobacillus acidophilus*. In a similar study conducted by Raghu et al [23], it was reported that garlic extract exhibited greater zone of inhibition against *Lactobacillus acidophilus*.

While when the extracts were compared with Chlorhexidine against *L. acidophilus*, the maximum antimicrobial activity was shown by 10% ethanolic extract of garlic (45.40 ± 0.03 mm) followed by 10% ginger extract (38.24 ± 0.06 mm) and least by 0.2%

Chlorhexidine (18.72 ± 0.29 mm) at all volumes ($p=0.001$). The zone of inhibition was found to increase as the volume of extracts increased; this is in accordance with the findings of Priti Yadav et al [20] and Nanasombat S [24] which suggests that 10% ethanolic garlic extracts could be used in the form of other formulations as an alternative for patients who wish for natural, economic products without artificial preservatives, flavors and colors.

The evaluation of toxicity and allergic potential of these plant extracts was not included in this study. Therefore, further in vitro and long-term in vivo studies are recommended to be conducted to get complete information regarding active constituents present in garlic in order to determine its toxicity, safety and pharmaco-kinetic properties and also to confirm and correlate the findings of this study to a clinical situation.

Conclusion

This in vitro study yielded significant findings regarding the antimicrobial efficacy of garlic, ginger, and Chlorhexidine against *Streptococcus mutans* and *Lactobacillus acidophilus*:

1. Garlic extract (10% ethanolic) exhibited superior antimicrobial activity against *L. acidophilus*, outperforming ginger extract (10% ethanolic) and 0.2% Chlorhexidine gluconate at all volumes (5-20 μ l), whereas its activity against *S. mutans* was relatively lower.
2. Conversely, 0.2% Chlorhexidine gluconate demonstrated maximum antibacterial potential against *S. mutans*, followed by garlic extract (10% ethanolic) and then ginger extract (10% ethanolic), except at the highest volume (20 μ l) where garlic extract surpassed Chlorhexidine.
3. A dose-dependent increase in antibacterial potential was observed for both garlic and ginger extracts, with

higher volumes yielding greater antimicrobial activity. Thus, the antibacterial properties of 10% ethanolic garlic extract suggest its potential therapeutic application in preventing dental caries and other oral infections. Garlic may emerge as a viable alternative to chlorhexidine mouthwash for reducing cariogenic pathogens in the oral cavity as they are easily available, cost-effective, socially acceptable with no or minimal side effects. These benefits herald a new era in herbal-based oral health maintenance, offering a natural and accessible solution for preventing oral infections.

Recommendations

The results of the present study have provided the justification for therapeutic potential of garlic. The practice of using garlic as supplementary or alternative medicine in developing countries like India will not reduce only the clinical burden of drug resistance development but also the side effects and cost of the treatment with allopathic medicine. However, to fully harness the benefits of garlic as a therapeutic agent, further research is necessary. The following recommendations are proposed:

Multifaceted pharmacological profiling: Investigate garlic extract's anti-inflammatory, hepatoprotective, anti-ulcer, and galactagogue properties to unveil its full therapeutic potential.

Sensory modification: Develop strategies to mask garlic's unpleasant odor and taste, incorporating flavoring agents or alternative delivery systems, while preserving its antimicrobial efficacy.

In-depth pharmacological characterization: Conduct comprehensive in vitro and long-term in vivo studies to:

- Elucidate the active constituents and their synergies
- Determine toxicity, safety, and pharmacokinetic profiles

- Validate and correlate findings with clinical outcomes, informing optimal therapeutic applications and dosing regimens.

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