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Antimicrobial Activity of *Zingiber officinale* (Ginger) Extract against *Escherichia coli* and *Staphylococcus aureus* Isolated from Vegetables Sold in Bokkos Market Plateau State, Nigeria

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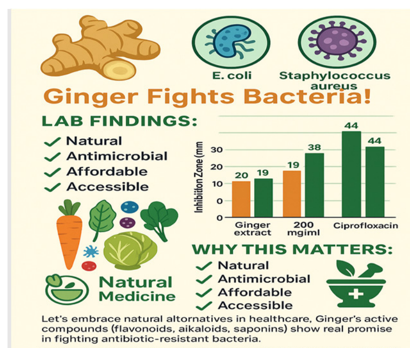
ABSTRACT

The growing threat of antibiotic resistance has intensified the search for alternative natural antimicrobials with broad-spectrum efficacy. This research aimed to assess the effectiveness of ginger rhizome extracts against Staphylococcus aureus and Escherichia coli bacteria found in vegetables obtained from Bokkos Local government area of Plateau State, Nigeria. The research determined the extract's minimum inhibitory concentration (MIC) to evaluate its potency against the identified bacterial strains. The ethanol extract of ginger inhibited the growth of S. aureus at various concentrations: 400 mg/ml resulted in a 20 mm clear zone, 200 mg/ml showed an 18 mm clear zone, 100 mg/ml displayed a 14 mm clear zone, and 50 mg/ml showed a 12 mm clear zone. However, compared to the standard ciprofloxacin (20mg/ml), the inhibition of S. aureus growth was lesser at all concentrations of the ginger extract, with a clear zone of 38 mm. Similarly, the ethanol extract of ginger rhizome showed inhibition against E. coli, with clear zones averaging 19 mm at 400 mg/ml, 16 mm at 200 mg/ml, 13 mm at 100 mg/ml, and 11 mm at 50 mg/ml, in contrast to the 44 mm produced by the standard Ciprofloxacin (20 mg/ml). Overall, the ethanol extract of ginger rhizome demonstrated a broad-spectrum antibacterial activity, ranging from 11 mm to 20 mm of inhibition zone. Thus, there was a very high significant difference ($F = 170.53$, $df = 4$, Adj.$R^2 = 97.27\%$, $P < 0.001$) in the mean zones of inhibition across the treatment groups. The maximum average inhibition against both Escherichia coli and Staphylococcus aureus was observed at 400 mg/ml concentration, while the minimum inhibition was noted at 50 mg/ml concentration. This study indicates that the ethanol extract of ginger rhizome possesses bacteriostatic properties against both gram-positive and gram-negative E. coli and S. aureus, which are commonly known as multi-drug resistant microorganisms.

Keywords: *Antimicrobial, Bokkos, Extract, Ginger, Vegetables*



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INTRODUCTION

For centuries, plants have been consistently utilized in the production of essential oils due to their relevance in medicine, pharmaceuticals, food industries, and biotechnology (Nabi *et al*., 2022). Ginger, scientifically known as *Zingiber officinale*, referred to as 'jinja' in Igbo, 'citta' in Hausa, and 'Atale' in Yoruba, serves not only as a culinary spice but also holds significance in medicinal applications due to its array of bioactive components (Abdullahi *et al*., 2020). This herbaceous perennial plant, characterized by an upright, slender stature, boasts a thick, fleshy rhizome beneath the soil and typically features one or more leafy stems reaching heights of up to 1.25 meters (Iotsor *et al*., 2019). As highlighted by Wang *et al*. (2020), Ginger exhibits antioxidant, antifungal, and antibacterial properties. Multiple research investigations have revealed that ginger possesses advantageous properties in alleviating pain, inflammation, fever, and ulcers.

Additionally, it has been observed to lower serum cholesterol levels and reduce gastric motility associated with nausea. "Its impact extends across a spectrum of health conditions, including allergies, thrombosis, osteoporosis, osteoarthritis, rheumatoid arthritis, degenerative diseases, atherosclerosis, and coronary diseases, as elucidated by Nabi *et al.* (2022). This underscores its efficacy in addressing a wide range of medical issues, emphasizing its significance in promoting overall well-being and combatting various ailments. Due to its potent effects against a wide range of viral, bacterial, and parasitic organisms, this particular herb has demonstrated considerable efficacy in combating infectious agents, as highlighted in a study by Imo and Za'aku (2019).

The rise in both the utilization and improper application of antibiotics has spurred microorganisms to develop resistance, a phenomenon that poses a growing challenge worldwide (Njobdi *et al*., 2018; Gali *et al*., 2016). This escalation in antibiotic usage has inadvertently provided the impetus for microorganisms to adapt and develop mechanisms to resist the effects of these drugs. Consequently, this resistance factor has become a significant concern on a global scale, as it undermines the efficacy of antibiotics and complicates the treatment of various infections (Gali *et al*., 2016). This has led to a necessity to seek alternative therapeutic medications for treating diseases, with a preference towards plant-based substances that have demonstrated fewer adverse effects (Njobdi *et al*., 2018).

The utilization of botanicals and herbal remedies in healthcare is an age-old practice, spanning across cultures and continents, employed to treat a variety of infectious and non-infectious ailments throughout history (Nabi *et al.,* 2022; Gupta and Birdi, 2017; Ngwu *et al.,* 2016).

According to a report by the World Health Organization, nearly 80% of individuals worldwide rely on traditional medicine, utilizing various plant extracts and herbs for their health and well-being (Abdullahi *et al.,* 2020). This reliance underscores the enduring significance of traditional healing practices across diverse cultures and regions, highlighting the widespread trust in natural remedies derived from botanical sources. Ginger is one of those plant extracts (Yadufashije *et al.,* 2020). Based on the antimicrobial properties of ginger (Oyinlola *et al.,* 2024), we hypothesized that its antimicrobial activity would be beneficial in our geographical region. Therefore, this study evaluated the antimicrobial effects of *Zingiber officinale* (ginger) extract against *Escherichia coli* and *Staphylococcus aureus* isolated from vegetables sold in Bokkos Market, Plateau State, Nigeria.

MATERIALS AND METHODS

Study location

The study was conducted in Bokkos Local Government Area, Plateau State Nigeria. Bokkos LGA is located between 90 180N and 90 00 00E of the Northern Tropical region of about latitude 150 & 300 North and South, East of the Equator, about 77 kilometers South of Jos, the capital city of Plateau State, Nigeria.

Sample collection

The assortment of vegetables including spinach, lettuce, tomatoes, cucumber, green peas, carrot, okra, cabbage, green beans, and ugwu were sourced from various locations such as Bokkos market, Maikatakwo, Ndar, and around the vicinity of Plateau State University. After gathering, each sample was correctly labeled and conveyed to the Microbiology laboratory situated at the National Veterinary Research Institute in Vom, Jos-south Plateau State, for subsequent microbial analysis.

Preparation of extracts

The ginger plant underwent a process of rinsing with distilled water to eliminate sand particles, followed by air drying for six weeks at room temperature. Subsequently, the dried components were crushed using a sterile laboratory mortar and ground into a uniform sample using a sterile electric blender, as described by Iotsor *et al.* (2019). A quantity of 120 grams of the powdered samples underwent extraction using 750 milliliters of methanol and n-Hexane through the cold maceration method, following the procedure outlined by Handa *et al.* (2008). After harvesting the plant materials, they underwent concentration through a rotatory evaporator set at 40°C. The resulting extract was subsequently freeze-dried to eliminate excess water content. Following this, it was transferred into sterile sample bottles and stored in a refrigerator at 4°C for future use. Portions of these plant extracts were then analyzed through phytochemical screening.

Phytochemical screening

The examination of secondary metabolites in plant extracts was conducted following Harborne's method (1973). This screening aimed to verify the existence or non-existence of specific phytochemical compounds attributed to the antimicrobial properties of plant extracts, including triterpenes, carbohydrates, flavonoids, glycosides, saponins, steroids, tannins, and alkaloids.

Preparation of nutrient agar

Twenty-eight grams of nutrient agar powder were dissolved in one liter of distilled water and sterilized at 121°C for 15 minutes using an autoclave. After cooling, the nutrient agar was poured into 24 petri dishes and left to solidify for a few minutes, following the procedure outlined by Njobdi *et al.* (2018) and Wright (1934).

Standardization of inoculum

The test organism was readied following the protocol outlined by Cheesbrough (2006). A single colony was selected from each culture of *E. coli* and *S. aureus*, then introduced into freshly prepared nutrient broth and left to incubate for 24 hours at 37°C. Subsequently, it was transferred to another batch of nutrient broth and incubated for 3 hours at 37°C using a sterilized wire loop. The turbidity of the test organisms for susceptibility testing was determined by comparing them to a 0.5 McFarland standard solution of Barium sulphate, which corresponds to a concentration of 1x106 CFU/mL.

Inoculation of test organisms

The organism was inoculated by employing the streaking technique on the nutrient agar plates.

Antibacterial assay

The antibacterial activity of the plant extracts was assessed using the agar well diffusion technique following the guidelines outlined by the Clinical and Laboratory Standards Institute (CLSI) (2006). Sterile cotton swabs were used to spread a standardized suspension onto the surfaces of sterile nutrient agar plates. Wells with a diameter of eight millimeters were created in the solidified agar using sterile core borers. The bottoms of the wells were subsequently sealed with 1 ml of sterile nutrient agar. Next, the wells were loaded with plant extracts at the desired concentrations (40 mg/ml and 80 mg/ml). After letting the plates sit at room temperature for approximately 3 hours to facilitate diffusion, they were then incubated at 37°C for 24 hours. The antibacterial efficacy of the plant extracts was determined by observing the presence of inhibition zones around the wells, indicating activity, while the absence of such zones indicated lack of activity. The effectiveness of plant extracts' antibacterial properties was evaluated by comparing them with amoxicillin (0.25µg/ml). Control plates were used, including extract sterility control (ESC), medium sterility control (MSC), and organism viability control (OVC).

Determination of minimum inhibitory concentration (MIC)

The minimum inhibitory concentration (MIC) was determined following the guidelines of the Clinical and Laboratory Standards Institute (CLSI) (2006). The plant extract was dissolved in a solution comprising 0.5 ml of DMSO and 4.5 ml of water. Each of the five test tubes received exactly 2 ml of sterile nutrient broth, followed by the addition of 2 ml of varying concentrations of the extract. The test organism was then inoculated into each labeled tube, excluding the negative control. The tubes were then placed in an incubator at 37°C for 24 hours. This process was repeated for the remaining extracts and test organisms. The MIC was identified as the lowest concentration of the extract that completely inhibited visible growth.

Determination of minimum bactericidal concentration (MBC)

The minimum bactericidal concentration (MBC) was established following CLSI (2006) guidelines. The test tube devoid of any observable growth was transferred onto sterile nutrient agar and kept in an incubator at 37°C for 24 hours. The lowest concentration where the organism failed to grow was identified as the minimum bactericidal concentration.

Data analysis

The information underwent analysis, inference, and subsequent presentation through tables and figures as necessary. Analysis was conducted to ascertain the MIC and MBC values. A comparison of the extract's impact on bacteria was executed by contrasting the zones of inhibition across various bacterial strains and the quantity of extracts utilized.

A one-way Analysis of Variance (ANOVA) was conducted to test whether there are significant differences in mean zones of inhibition across different concentrations of ginger extract (400, 200, 100, 50 mg/ml) within each organism (*S. aureus* and *E. coli*). P value less than 0.05 were deemed statistically significant.

Table 1: Culture and morphological characteristics of bacterial isolates

Bacterial Isolate (BI) Code	Blood Agar	MacConkey Agar	Nutrient Agar	Probable Organism
BI1	Greenish discoloration, Alpha hemolytic	Pale yellow colonies	Round, convex and fairly large yellow or white colonies	*Staphylococcus aureus*
BI2	No Haemolysis	red/pink non-mucoid colonies	Large, thick, grayish white, moist, smooth, opaque or translucent disc.	*Escherichia coli*
BI3	red/pink non-mucoid colonies	Brown-green colonies	Greenish coloration, large, opaque, flat colonies with irregular margins and distinctively fruity odor colonies.	*pseudomonas aeruginosa*
BI4	No Haemolysis	Inhibited	Colonies appear large, mucold and white in color	*Klebsiella species*
BI5	Rough, opaque, fuzzy white or slightly yellow with jagged edge.	Large, smooth, pink colonies with mousy smell	Opaque, fuzzy white or slightly yellow with jagged edges	*Bacillus species*
BI6	They appear as medium to large sized grey olonies.	Appear as non –lactose fermenter up to 24 hours; however after48hours colonies are light pink mucoid colonies.	Grayish to white – colored large, circular and convex colonies.	Enterobacter species
BI7	Forms circular colonies and are grayish in color due to beta heamolysis.	Circular colonies that are 1-3mm in diameter, grayish in color due to beta –hemolysis after three days become dark green.	Greyish to white-colored large, circular and convex colonies	Aeromonas species

Table 2: Biochemical reaction of bacterial isolates

Indole Test	Catalase Test	Coagulase Test	Vogues Proskauer	Methyl red	Citrate	Urease test	Gram Staining	Organisms
_	+	+	+	+	+	+	+	*Staphylococcus aureus*
+	+	+	_	+	_	_	-	*Escherichia coli*
_	+	_	_	_	+	+	-	*Pseudomonas aeruginosa*
_	+	_	+	_	+	+	-	*Klebsiella* species
_	+	_	+	_	+	+	-	*Bacillus* species
_	+	/	+	_	+	_	-	*Enterobacter* species
+	+	/	_	+	+	_	-	*Aeromonas* species

Key: + = Positive; - = Negative

RESULTS

Bacterial isolation

In this study, a total of 40 samples were collected from Bokkos market, Maikatakwo, Ndar and across Plateau State University vicinity and investigated for the presence of bacteria. Of this number, seven species of bacteria, *Staphylococcus aureus, Escherichia coli, Klebsiella species, Enterobacter species, Bacillus species* and *Pseudomonas aeruginosa* were isolated and identified on the basis of their cultural, morphological characteristics on the various culture media. Table 1 shows the cultural and morphological characteristics of the bacterial isolates on the various culture media used.

Biochemical and gram staining

Table 2 shows the result of biochemical and gram staining result.

Bacteria isolated

The bacteria isolated from the samples collected are presented in (Table 3).

Table 3: Bacteria isolated from the samples

SAMPLE	Sample code	Bacteria isolated
Carrot	A1	*Klebsiella aerogenes*
	B1	*K. aerogenes*, *Aeromonas* species (spp.)
	N1	*Enterobacter* species
	M1	*Eschericha coli*
Cabbage	A2	*Klebsiella aerogenes*
	B2	*Aeromonas* species
	N2	*Enterobacter* species
	M2	*K. aerogenes, Aeromonas* species
Green beans	A3	*K. aerogenes*
	B3	*Aeromonas* species, *Bacillus* spp.
	N3	*Enterobacter* species
	M3	*Staphylococcus aureus*
Green peas	A4	*Aeromonas* species
	B4	*Bacillus* spp.
	N4	*Staphylococcus aureus*
	M4	*Enterobacter* species, *Bacillus* spp., *Aeromonas* species
Tomatoes	A5	*K. aerogenes*
	B5	*K. aerogenes*
	N5	*K. aerogenes*
	M5	*K. aerogenes, Aeromonas* species
Spinach	A6	*Aeromonas* species, *K. aerogenes*
	B6	*K. aerogenes, Bacillus* spp.
	N6	*Bacillus* spp., *Aeromonas* species
	M6	*Aeromonas* species
Ugu	A7	*K. aerogenes,* Coagulase-negative Staphylococci
	B7	*Aeromonas* species, *Bacillus* spp
	N7	*K. aerogenes*
	M7	*Pseudomonas aeruginosa*
Cucumber	A8	*K. aerogenes*
	B8	*Aeromonas* species
	N8	*Escherichia coli*
	M8	*Pseudomonas aeruginosa*
Okro	A9	*Aeromonas* species, *Bacillus* spp.
	B9	*Aeromonas* species, *Bacillus* spp.
	N9	*Aeromonas* species, *Bacillus* spp.
	M9	*Pseudomonas aeruginosa*
Garden egg	A10	*Aeromonas* species, *K. aerogenes*
	B10	*Staphylococcus aures*
	N10	*K. aerogenes*
	M10	*Pseudomonas aeruginosa*

Keys: A: Across. B: Bokkos N: Ndar M: Maikatako

Table 4: Phytochemical extract of ginger rhizome using ethanol.

Sample I.D	Sapponins (%)	Tannins (mg/100g)	Steroids (%)	Alkaloids (%)	Flavonoids (%)
Ginger rhizome	4.00	2.23	0.56	8.54	9.96

Phytochemicals of the extract from ginger

Five metabolites were recorded from ethanolic ginger extract as shown in (Table 4).

Antimicrobial activities of ethanol extract of ginger rhizome

The ethanol extract of ginger rhizome inhibited the growth of *Staphylococcus aureus* at 400 mg/ml concentrations with a clear zone of 20 mm, at 200 mg/ml concentrations with clear zone of 18mm, at 100mg/ml concentrations with clear zone of 14 mm and at 50 mg/ml concentrations with a clear zone of 12 mm (Table 5). The ethanol extract of ginger rhizome also produced inhibition effect against *Escherichia coli* with an average of 19 mm of clear zone at 400 mg/ml concentrations, 16 mm at 200 mg/ml

Table 5: Antimicrobial activities of ethanol extract of ginger rhizome against *Staphylococcus aureus* and *Escherichia coli*

Organisms	Concentration of Extract (mg/ml)/Average Diameter of Zones of Inhibition (mm)				Ginger Extract	Positive control
	400	200	100	50		**Ciprofloxacin (20 mg/ml)**
S. aureus	20	18	14	12	Aqueous	38
S. aureus	20	18	12	10	Aqueous	38
Average	20	18	13	11		
E. coli	18	16	14	12		44
E. coli	20	16	12	10		44
Average	19	16	13	11		

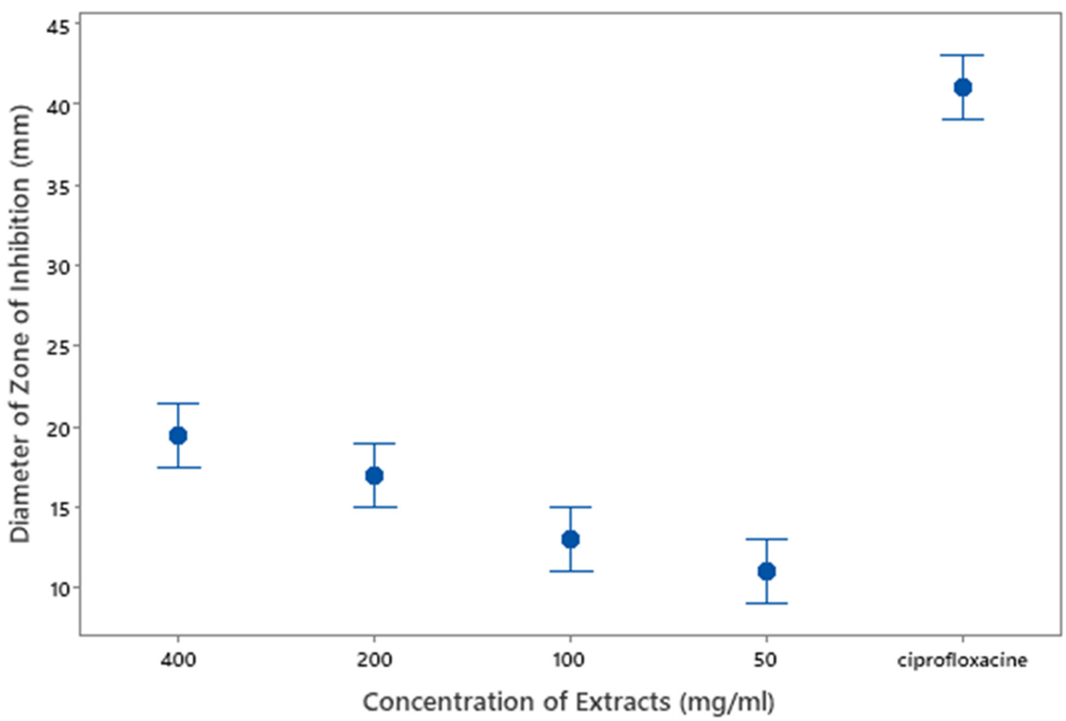

Figure 1: Mean zones of inhibition across the treatment groups

concentrations, 13 mm at 100 mg/ml concentrations and 11 mm at 50 concentrations against 44 mm produced by the standard Ciprofloxacin (20mg/ml). Consequently, there was a very high significant difference (F = 170.53, df = 4, Adj.R^2 = 97.27%, P < 0.001, Figure 1) in the mean zones of inhibition across the treatment groups.

Mininum inhibitory concentration (MIC) for ethanol extract of ginger rhizome

The result showed that at 100 mg/ml concentration of ethanol extract of ginger rhizome, both *Escherichia coli* and *Staphylococcus aureus* presented no turbidity. However, at 50 mg/ml, 25 mg/ml, 12.5 mg/ml, 6.25 mg/ml and 3.125 mg/ml, there was no turbidity revealing that there was growth (Table 6).

Minimum bactericidal concentration (MBC) of ethanol extract of ginger rhizome

The result revealed that, the ethanol extract of ginger rhizome produced no effect against *Staphylococcus aureus* and *Escherichia coli* at all concentrations (Table 7).

Positive control (Ciprofloxacin) minimum inhibitory concentration (MIC)

The result shows that both *Staphylococcus aureus* and

Table 6: Minimum Inhibitory Concentration (MIC) for Ethanol Extract of Ginger Rhizome

Organism	Concentration of Extract MIC (mg/ml)/						Extract
	100	50	25	12.5	6.25	3.125	
E. coli	-µ	+	+	+	+	+	Aqueous
S. aureus	-µ	+	+	+	+	+	Aqueous

KEY: - = no turbidity, + = presence of turbidity, µ MIC

Table 7: Minimum bactericidal concentration (MBC) of ethanol extract of ginger rhizome

Organism	Concentration of Extract MIC (mg/ml)/						Extract
	100	50	25	12.5	6.25	3.125	
E. coli	+	+	+	+	+	+	Aqueous
S. aureus	+	+	+	+	+	+	Aqueous

KEY: - = no growth, + = presence of growth.

Table 8: Positive Control (Ciprofloxacin) Minimum Inhibitory Concentration (MIC)

Organism	Ciprofloxacin (mg/ml)								
	20	10	5	2.5	1.25	0.625	0.3125	0.1562	MIC (mg/ml)
E. coli	-	-	-	-	-	-	-	µ	< 0.1562
S. aureus	-	-	-	-	-	-	-	+	0.3126

KEY: - = No turbidity, + =Turbidity, µ = MIC

Table 9: Positive control (Ciprofloxacin) minimum bactericidal concentration (MBC)

Organism	Ciprofloxacin (mg/ml)								
	20	10	5	2.5	1.25	0.625	0.3125	0.1562	MBC (mg/ml)
E. coli	-	-	-	-	-	-	β	+	0.3125
S. aureus	-	-	-	-	-	β	+	+	0.625

KEY: - = No growth, + = presence of growth, β = MBC

Escherichia coli are inhibited at all concentrations of the positive control (Table 8).

Positive control (Ciprofloxacin) minimum bactericidal concentration (MBC)

The result shows that both *Staphylococcus aureus* and *Escherichia coli* are inhibited at all concentrations of the positive control except at 0.3125 mg/ml, 0.1562 mg/ml. *Staphylococcus aureus* is found to be inhibited at 0.625 mg/ml (Table 9).

DISCUSSION

In the conducted research, it was observed that the organisms under investigation displayed susceptibility to different concentrations of the plant extracts. The effectiveness of ethanol extracts from ginger in inhibiting bacterial growth is believed to be due to the existence of bioactive elements, as noted by Dixon and Jeena (2017) as well as Ponmurugan and Rajaram (2012). These findings suggest that the antibacterial properties of ginger extracts can be linked to the presence of certain chemical compounds within them, potentially offering promising avenues for further exploration in the realm of natural antibacterial agents. The occurrence of flavonoids, saponins, and alkaloids in the extracts remained in line with findings from earlier research conducted by Abdullahi *et al.* (2014), Aliyu *et al.* (2017), Iotsor *et al.* (2019) and Faris *et al.* (2025), thereby affirming the consistency of our results with prior studies. These compounds, known for their diverse pharmacological activities, have been extensively studied in various medicinal plants, and our results further support their presence in the extracts under investigation. The study revealed significant antibacterial efficacy in ginger extracts, aligning with findings by Aliyu *et al.* (2017), who also noted potent antibacterial properties of ginger extract across diverse bacterial strains. However, variations in results are attributed to differences in ginger preparations and concentrations utilized. The observed antibacterial activity in ginger extracts could be attributed to the presence of active components with in vitro effectiveness against clinical isolates, or perhaps the concentrations employed were sufficient to induce antimicrobial effects against the organisms, as suggested by Cheeke (1989) and corroborated by Aliyu *et al.* (2017). This underscores the potential of ginger extracts as a natural antimicrobial agent and warrants further investigation into its mechanisms of action and potential applications in combating bacterial infections.

With an adjusted R^2 value of 97.27%, the one-way ANOVA analysis showed that the concentration of ginger extract significantly affected the inhibition zones against test organisms, suggesting that the model accounts for a sizable amount of the observed variance. This implies that *Zingiber officinale*'s ethanol extract's antibacterial activity is greatly increased by raising its concentration. In line with previous findings by Wang *et al.* (2020), who also noted notable variation in inhibition zones across graded concentrations of ginger extract against *Staphylococcus aureus* and *Escherichia coli*, the strong statistical relationship highlights the extract's dose-dependent effect on microbial inhibition.

The ethanol-extracted ginger also showed increasing zones of inhibition with concentration, as shown by Obi and Bukar (2021), however their model explained a little less variation (Adj. R^2 = 92.1%). This conclusion is further supported by the current investigation, which shows a stronger concentration–response association. Additionally, our results support those of Singh and Immanuel (2019), who found that ginger extracts had strong antibacterial activity, especially at doses greater than 200 mg/mL. They attributed this to the combined effect of gingerol and other bioactive substances. A high minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) typically indicate limited effectiveness, while low MIC and MBC values signify potent activity of a given plant material against bacteria. In the context of this investigation, it was observed that the ethanol extract derived from ginger rhizome demonstrated inhibitory effects on the growth of *E. coli* and *S. aureus* only when administered at a concentration of 100mg/ml. This suggests that across various concentrations tested, the ethanol extract exhibited no significant impact on the growth of these bacterial strains in this particular study. This finding aligns with the results reported by Iotsor *et al.* (2019), reinforcing the notion of limited efficacy against *E. coli* and *S. aureus*.

Conclusion

The findings of this research indicate that ginger root possesses inhibitory effects against *E. coli* and *S. aureus* in laboratory conditions. These properties suggest that ginger could serve as a viable alternative to antibiotic medications in the treatment of infectious diseases caused by bacterial pathogens. This potential highlights the significance of natural remedies derived from plants in combating bacterial infections, potentially offering safer and more sustainable treatment options. Further exploration of ginger's therapeutic properties could contribute to the development of novel treatments for bacterial illnesses, reducing dependence on traditional antibiotics and potentially mitigating issues such as antibiotic resistance.

Recommendation

Phytochemicals are emerging as highly promising substitutes for traditional antibiotics, especially given the decreasing availability of conventional options. Their effectiveness in treating infections caused by pathogens suggests a prudent shift towards their utilization. Moreover, incorporating plants into the formulation of modern medicines within developing nations could mitigate various risks associated with conventional antibiotics, such as resistance development, misuse, exorbitant costs, and adverse effects. This emphasises the importance of concerted efforts by governmental and non-governmental entities to prioritize the development and utilization of herbal remedies. By doing so, we can foster a more sustainable and resilient approach to healthcare delivery while safeguarding against the pitfalls associated with reliance solely on conventional antibiotics.

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