

Natural alternatives as antibiotics: a comparative study of alcoholic extract of ginger root and trimethoprim drug against *Salmonella* bacteria.

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Abstract:

Intestinal diseases are considered health problems that lead to the emergence of harmful microbes that are resistant to many drugs and the use of natural materials poses a great challenge to health as they increase their ability to reduce the symptoms of potentially fatal infectious diseases.

Objective: This study aimed to use alternative plants to be approved as drugs to reduce the ability of the bacteria. **Methods:** Ginger root extract was prepared and tested using the minimum inhibitory concentration (MIC) technique. Its inhibitory activity against four bacterial isolates was evaluated using agar plates. The extract's effect was compared with that of a standard antibiotic (trimethoprim). In addition, chemical analysis was performed to identify the plant's active ingredients using chromatography techniques.

Results: The results showed that Ginger alcoholic extract was able to have excellent antibacterial activity, which was determined by investigating the minimum inhibitory concentration by taking different concentrations (2-1024 µg/mL). The anti-biofilm activity of the four *Salmonella* was determined and the results showed that the inhibition by zone ranged between 20-26 mm for the extract of ginger roots compared to the Trimethoprim drug. **Conclusions:** Ginger Alcoholic extract represents a suitable alternative to chemical antibiotics to combat *Salmonella* bacteria

Keywords: Ginger root, Trimethoprim drug, Minimum Inhibitory Concentration, Minimum Bactericidal Concentration, gas chromatography-mass spectrometry

1-Introduction:

Foodborne bacterial infections are a major concern for both developed and developing countries, posing significant health risks, particularly to vulnerable populations. The elderly and children are more susceptible due to their weaker immune systems. Weakened immunity in children may result from underlying medical conditions or genetic factors, while in the elderly; it is often associated with the natural decline in physiological functions that accompany aging. Digestive disorders are among the most common consequences of foodborne bacterial infections, directly affecting the body's ability to absorb essential nutrients. This can severely impair the growth and overall development of children and worsen the health of the elderly. These risks highlight the urgent need for strict food safety measures and preventive strategies at all stages of food production and handling [1]. To combat gastrointestinal infections caused by *Salmonella* species, antibiotics such as ampicillin, cefoxitin, erythromycin, chloramphenicol, and tetracycline are commonly used. These antibiotics are known for their effectiveness in targeting the bacterial strains responsible for intestinal inflammation, diarrhea, and abdominal pain associated with salmonellosis. In addition to conventional antibiotics, certain medicinal plants and herbs have shown potential as natural alternatives due to their bioactive compounds with strong antibacterial properties. These natural agents can support or enhance treatment by inhibiting the growth of *Salmonella* and improving gut health [2]. Trimethoprim/sulfamethoxazole (TMP/SMX) is frequently used for the treatment of diverse infections and serves as a standard antibiotic for several therapeutic reasons. Trimethoprim/sulfamethoxazole (TMP/SMX) must be administered correctly to prevent adverse effects such as dermal irritation (e.g., rash), gastrointestinal complications, bone marrow suppression, renal dysfunction, hepatotoxicity, and electrolyte imbalances, which require distinct management to mitigate these side effects [3]. Recently, focus has shifted toward natural alternatives and complementary therapies. Some medicinal herbs have shown significant efficacy in combating *Salmonella* species. Ginger (*Zingiber officinale*) contains active chemicals, including gingerol and shogaol, which exhibit strong antibacterial properties and help relieve gastrointestinal inflammation. Garlic (*Allium sativum*) has broad-spectrum antibacterial capabilities attributed to allicin, a chemical active against many infectious diseases, including salmonella. These natural compounds may offer additional therapeutic benefits, particularly in cases of antibiotic resistance, or in promoting gut health in conjunction with conventional medications [4].

The judicious application of antibiotics is essential to guarantee effectiveness in attaining sufficient antibacterial action and reducing concentration-dependent toxicity, necessitating the avoidance of overdose, particularly in the context of antibiotic resistance. Therapeutic Intervention the dose guidelines for trimethoprim/sulfamethoxazole (TMP/SMX) predicated on the trimethoprim (TMP) component, which may be taken orally or intravenously for the management of bacterial infections [5] .

One of the main causes of gastrointestinal diseases is Salmonella bacteria, which causes gastroenteritis, diarrhea, high temperatures, and other symptoms if not treated properly. It is transmitted through foods and food such as red meat, chicken, duck, etc. There are many Salmonella, the most important of which are Salmonella typhi, non-typhi, and common non-typhi invasive Salmonella, which are transmitted dangerously through the mouth and feces, which pose a threat and are the most dangerous [6]. Salmonella is a dangerous pathogenic bacterium that can enter the host body due to its protein and villi content, as well as the host's weak immune system. This makes it difficult to eliminate it, but it also helps the bacteria survive in the host body [7] Salmonella bacteria can also get into the body of a host through genes linked to pathogens, like non-phagocytic cells, and by activating proteins in the mucosa that are part of the epithelial membrane [8]. Biofilms, which are made up of microbial cells clumped together on the surface, are one of the main things that determines whether bacteria live or die [9]. The surface is made up of polymeric materials like deoxyribonucleic acid and proteins. Biofilms and environmental stress is linked because bacteria use adaptation mechanisms, acidity, ultraviolet rays, and disinfection to keep the cell wall strong. The stages of biofilms that bacteria go through are adhesion, maturation, and detachment [10].

In recent studies, researchers have focused on finding effective herbal medicines that work as an alternative to traditional chemical medicines due to their negative aspects, as they work to inhibit many bacteria, including the most dangerous staphylococci and enterococci. As a result, researchers have become interested in finding effective alternative antibiotics that are less expensive [11]. Ginger is a traditional herbal plant widely used to treat microbial infections and antioxidants due to its bioactive chemical compounds and minerals. Ginger, a herbaceous plant of the genus Zingiberaceae, belongs to the root family [12]. The pungent taste of ginger is due to the presence of a compound called gingerol, but when cooked or dried, it turns into shogaol, which is attributed to the hot taste. It is a powerful antioxidant and cancer-killer, as it contains important compounds such as

Sesquiphellandrene and Octadecenoic acid that inhibit the growth of toxic cells and prevent their spread to healthy cells [13].

This study aims to compare the antibacterial effectiveness of natural ginger root extract and the synthetic antibiotic trimethoprim drug against Salmonella bacteria. The research involves laboratory experiments to assess the ability of each treatment to inhibit bacterial growth and to evaluate the potential of ginger as a natural alternative to conventional antibiotics in combating bacterial infections.

2. Materials and Methods:

2.1. Materials: A pharmaceutical strip containing, according to the labeled concentration, 400 mg of sulfamethoxazole and 80 mg of trimethoprim (Trimethoprim/Sulfamethoxazole), manufactured by the General Company for Pharmaceutical Industry – Samarra/Iraq, was used for conducting the study.

2.2. Salmonella bacterial isolates: Four different bacterial isolates were obtained from the microbiology laboratory. These pre-collected isolates were stored under suitable storage conditions until used in experiments.

2.3. Extraction of Ginger plant: The collected Ginger roots (*Zingiber officinale*) were washed with water to remove impurities and dust. The cleaned sample was then cut into small pieces, dried, and ground into a fine powder. 25 g of ginger powder was weighed using a precision electronic balance. The weighed powder was soaked in 50 ml of high-purity methanol, and the mixture was shaken on an electric shaker at 120 rpm for 4 h at room temperature. Following the soaking process, the solution was filtered using suitable filter paper to remove solids. Store the resulting extract in a tightly closed container and away from light in preparation for use in subsequent experiments [14].

2.4. Analytical characterization of ginger extract with gas chromatography-mass spectrometry (GC-MS): After measuring and transferring the required amount of *Z. officinale* powder to a sealed vial, it was subjected to methanol treatment to enhance infusion. The extract was filtered and dried using a vacuum distillation apparatus after 24 hours. The remaining residue was subsequently analyzed using GC-MS. A Shimadzu GCMS-QP 2010, SE was used for GC-MS analysis. The system consists of a gas chromatography-mass spectrometry (GC-MS) coupled to an Elite-I RMS 5 fused silica capillary column made entirely of polydimethylsiloxane. A detection energy of 70 eV was used. The injected sample volume was 1 μ L, using a 10:1 split ratio, with helium (99.9%) as the carrier gas at a constant flow rate of 1 mL/min. The ion source and injector temperatures were set at

250°C and 260°C, respectively. The oven was programmed to start at 110°C, increasing by 5°C per minute until reaching 260°C, where it was held constant for three minutes. Mass spectra, including components with intensities ranging from 50 to 650 Daltons, were acquired with a 0.5-second scan period. Turbo Mass software facilitated the management of mass spectra and chromatograms, allowing comparison of the average peak area of each component to the total area to determine its percentage [15].

2.5. Determination of minimum inhibitory concentration (MIC):

Resazurin dye solution was prepared by dissolving 0.015 g of resazurin in 100 ml of distilled water, mixing well, and storing at 4°C until use. Serial two-fold dilutions (from 2 to 1024 µg/ml) were then performed in sterile microliter plates using Mueller-Hinton broth as the culture medium. All wells were inoculated with 20 µl of a bacterial suspension containing Salmonella. Ginger extract was also tested as an active ingredient in separate wells. The plates were incubated at 37°C for 18–24 h. After the incubation period, 20 µl of resazurin solution was added to each well, and color changes were monitored to determine the minimum inhibitory concentration (MIC), with blue indicating the absence of bacterial growth (effective inhibition), while pink or colorless indicates bacterial growth [16].

2.6. Evaluation of the antibacterial activity of ginger root extract and trimethoprim drug against Salmonella bacteria.

The alcoholic extract of ginger root and trimethoprim at a concentration of 64 µg/ml were tested for their ability to inhibit bacterial growth using the agar well diffusion method. Four bacterial isolates were cultured, incubated at 37°C for 24 h. A volume of 0.1 ml of each bacterial suspension was evenly distributed over the surface of agar plates. After the plates were allowed to stand for a short period, three 5 mm diameter wells were aseptically created in each plate. 50 µl of the tested samples were added to the side wells, while distilled water (D.W.) served as a negative control in the central well. The plates were incubated again at 37°C for 24 h. After incubation, the diameters of the inhibition zones were measured in millimeters to determine the antibacterial activity of both the extract and the drug. It is worth noting that 64 µg/mL was chosen as a standardized test concentration for assessing inhibitory efficacy [17].

3. Results and Discussion:

3.1. GC-MS analysis:

Ginger root, which showed effective antibacterial activity, was subjected to GC-MS analysis to detect and identify the components present in it. Through broad-spectrum analysis of the detected compounds, about 26 compounds

were identified as shown in Figure 1. The chemical components of ginger were identified by gas chromatogram-mass spectrometry, the most prominent of which were fatty acid compounds, terpenes and others. In this study, D-Limonene (1.39%), Camphene (6.45%), 2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene (2.37%), Geraniol (9.56%), 1,8-Cineole (5.84%), Camphene (4.92%), Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl (9.54%), beta-Sesquiphellandrene (12.99%), n-Hexadecanoic acid (6.15%) and other compounds were found as shown in Table 1.

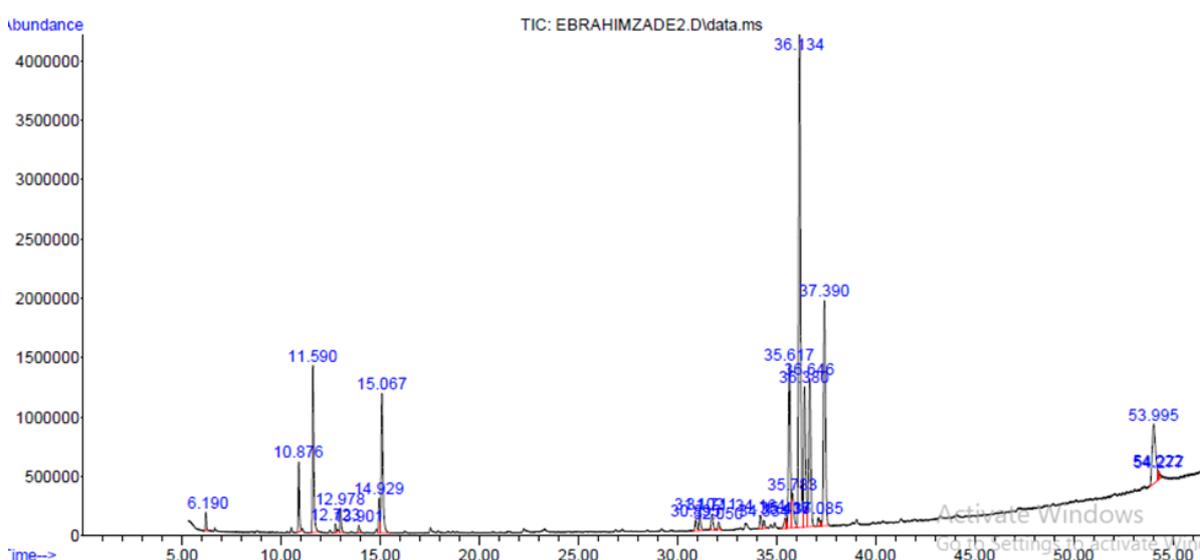


Figure 1: Chromatography (TIC) obtained from gas chromatography-mass spectrometry analysis of the alcoholic extract of ginger root

In a comparative study conducted by Kamal et al. [18], several volatile compounds were identified that play an important role as antibacterial agents. Camphene is a terpene known for its multiple biological activities, particularly its antibacterial and antifungal effects. D-Limonene is a cyclic compound with anti-inflammatory and antioxidant properties, enhancing therapeutic efficacy. Additionally, β -Elemene, a sesquiterpene with antitumor and some antimicrobial activity, was also identified.

In addition, α -Cubebene, which has been reported to be present in ginger oils, was found to be an important volatile component. Trans- α -bergamotene, (E)- β -farnesene, and trans- β -farnesene are members of the farnesine family, which play a role in ginger's biological activity, including its antibacterial and anti-inflammatory effects. One of the main compounds in ginger is zingiberene, also known as 1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)-2-methyl, a sesquiterpene compound that constitutes a significant proportion

of the volatile oil and contributes significantly to the antibacterial activity and therapeutic properties of ginger oil.

Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl, was also identified in GC-MS analyses of ginger, reflecting the diverse chemical composition of aromatic compounds in the oil. Finally, another sesquiterpene compound, germacrene, has anti-inflammatory and antioxidant properties, supporting the role of ginger oil in medical and health applications.

Table1: Identification of active compounds by gas chromatography-mass spectrometry of Alcoholic ginger extract. .

No.	name of the compounds	peak Area %	Retention Time
1	Benzene, methyl-	0.55	6.19
2	2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene	2.37	10.877
3	Camphene	6.45	11.591
4	Bicyclo[3.1.1]heptane, 6,6-dimethyl-2-methylene	0.34	12.723
5	1,6-Octadiene, 7-methyl-3-methylene	0.94	12.98
6	1,3-Cyclohexadiene, 2-methyl-5-(1-methylethyl)-	0.33	13.9
7	D-Limonene	1.39	14.929
8	4(10)-Thujene	7.15	15.066
9	1.xi.,6.xi.,7.xi.-Cadina-4,9-diene	0.6	30.898
10	.alpha.-Cubebene	0.89	31.103
11	.beta.-Elemene	0.91	31.709
12	trans-.alpha.-Bergamoten	0.34	32.052
13	(E)-.beta.-Famesene	0.68	34.167
14	trans-.beta.-Farnesene	0.39	34.333
15	1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)-2-methyl-,	0.48	35.418
16	italicene	0.27	35.436
17	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl	9.54	35.618
18	Germacrene	1.97	35.784
19	1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)-2-methyl-, [S-(R*,S*)]-	27.41	36.133
20	alpha.-Farnesene	8.31	36.379
21	.beta.-Bisabolene	8.69	36.647
22	Bicyclo[4.4.0]dec-1-ene, 2-isopropyl-5-methyl-9-methylene-	0.45	37.087
23	.beta.-Sesquiphellandrene	12.99	37.39
24	n-Hexadecanoic acid	6.15	53.993
25	cis-13-Octadecenoic acid	0.22	54.279
26	9-Octadecenoic acid (Z)-	0.21	54.222

3.2. Evaluation of ginger and trimethoprim drug efficacy against bacterial growth via MIC determination.

Microliter plates containing resazurin dye were used to test the effectiveness of ginger extract and trimethoprim in inhibiting the growth of four different *Salmonella* isolates, to determine the minimum inhibitory concentration (MIC) for each sample. As shown in Figure 1, the numbers above the plates indicate the concentrations of ginger and trimethoprim added to the wells, which ranged from 2 to 1024 $\mu\text{g/ml}$

The results showed that the lowest inhibitory concentration of trimethoprim for the first and fourth isolates was 64 $\mu\text{g/ml}$; color of the resazurin dye changed to blue, indicating complete cessation of the bacterial metabolic activity and thus complete inhibition at this concentration.

For the ginger alcoholic extract, the minimum inhibition level was 256 $\mu\text{g/ml}$, while the highest inhibition level was observed for most isolates at 512 $\mu\text{g/ml}$ for the ginger root extract. These results indicate that there is variation in the response of different isolates to the treatments used (ginger alcoholic extract, trimethoprim drug). The lethal concentration for each isolate is documented in Table 1.. A comparable finding was reported by Odo [19], assessing the antibacterial efficacy of various doses of ginger and tomato extracts against distinct bacterial strains.

Table 2: Assessment of the Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) of Ginger Alcoholic Extract and Trimethoprim against *Salmonella*

Isolates	Trimethoprim drug $\mu\text{g/ml}$		Alcoholic extract of ginger root/ $\mu\text{g/ml}$	
	MBC	MIC	MBC	MIC
Salmonella.1	128	64	512	256
Salmonella.2	256	128	512	256
Salmonella.3	256	128	----	1024
Salmonella.4	128	64	512	256

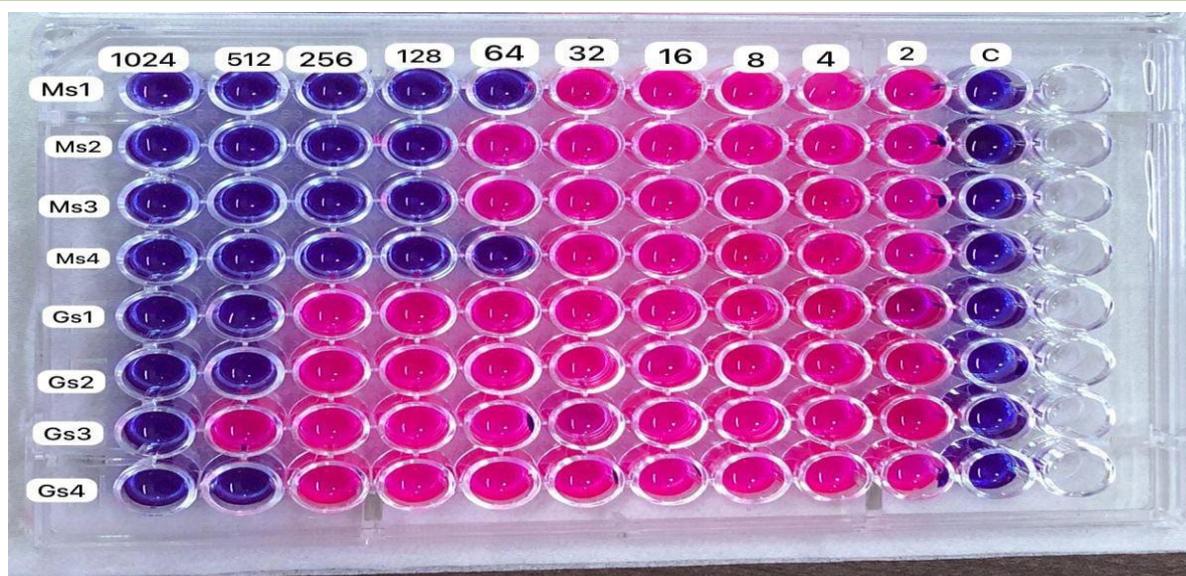


Figure 1: Evaluation of the Antibacterial Activity of Alcoholic Ginger Extract (Gs) and Trimethoprim drug (Ms) Against Salmonella Isolates Using the Broth Micro dilution Method

3.3. Determination of antibacterial activity using agar diffusion method against alcoholic ginger extract and Trimethoprim drug:

The minimum inhibitory concentration of ginger extract and drug was determined by inhibiting the growth of Salmonella. By microscopic dilution technique of broth samples, using Mueller Hinton agar medium, by considering the formation or absence of the diameter of the inhibition zone tested by Kirby-Bauer method and based on the inhibition zone formed by the effectiveness. In Table 3, it was found that the inhibition zones ranged between (20-26 mm) of ginger and drug against four Salmonella isolates, the spread of the agar well at the concentration of 64 $\mu\text{g/ml}$, while the inhibition zones of the drug ranged between (28-34 mm).

As shown in Figure 2, the observed results are closely consistent with those reported by [20], which documented an inhibitory concentration of 20–26 mm for the four Salmonella isolates. The ginger alcoholic extract demonstrated significant antibacterial activity against all four bacterial isolates evaluated. The antibacterial efficacy of the ginger extract is related to its solubility, which allows interaction with bacterial cell membranes. This activity is attributed to the presence of aromatic groups and bioactive compounds in the ginger alcoholic extract [21]. Previous studies have suggested that ginger may exhibit antibacterial efficacy comparable to conventional antibiotics against Salmonella species, possibly due to structural differences in bacterial cell membranes [22]. Furthermore, the functional

groups—active and inactive—present in ginger roots may contribute to bacterial inhibition by disrupting key cellular processes. In support of this, recent findings by Oyinlola et al. [23] revealed that ginger root extract significantly disrupts the integrity of the cell wall and cell membrane in *Salmonella*, inhibiting intracellular bacterial growth and impairing membrane stability, enhancing its potential as an effective natural antimicrobial agent.

Table 3: Evaluation of Antibacterial Activity of alcoholic Ginger Extract and Trimethoprim drug using the Agar Diffusion Method.

Isolate	Alcoholic Ginger extract (mm)	Trimethoprim drug / (mm)
Salmonella 1	20	28
Salmonella 2	25	33
Salmonella 3	26	30
Salmonella 4	24	34

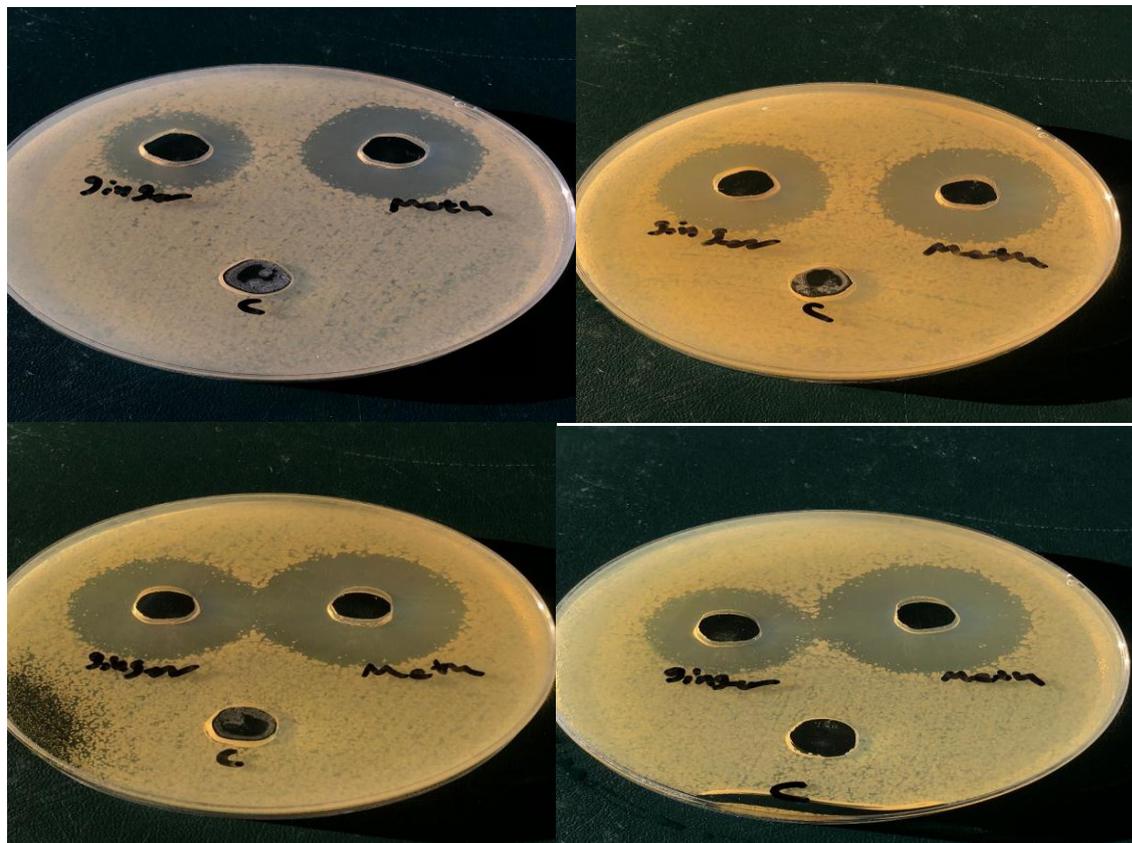


Figure 2: Zones of bacterial growth inhibition around the alcoholic ginger extract, Trimethoprim drug and control for four *Salmonella* isolates.

Conclusion: In this study, natural plant compounds were investigated as potential alternatives to the antibiotic trimethoprim to combat *Salmonella* species. The primary objective was to evaluate and compare the antibacterial efficacy of ginger alcoholic extract with that of the drug trimethoprim. Chromatographic analyses were used to identify the bioactive components of the plant extract, revealing the presence of compounds such as d-limonene, α -cubine, trans- α -bergamotene, (E)- β -farnesene, and trans- β -farnesene. These phytochemicals are known for their antimicrobial properties and suggest the potential of ginger as an effective alternative to conventional antibiotics. The results demonstrated that the ginger alcoholic extract significantly inhibited the formation and growth of bacterial biofilms. The ginger alcoholic extract exhibited promising antibacterial activity, suggesting its potential use in the development of therapeutic agents against typhoid fever and other bacterial pathogens, including *Staphylococcus aureus* and *Escherichia coli*.

References:

- [1]Khamda, R., Divsalar, F., Tirabadi, N. M., Sani, N. N., & Charmduzi, F. (2024). A Systematic Review of Digestive Problems in Children and the Elderly Involved in Infectious Diseases, Relying on Nursing and Medical Measures. *Pakistan Heart Journal*, 57(1), 256-264.
- [2] Jubair, N., Rajagopal, M., Chinnappan, S., Abdullah, N. B., & Fatima, A. (2021). Review on the antibacterial mechanism of plant-derived compounds against multidrug-resistant bacteria (MDR). *Evidence-Based Complementary and Alternative Medicine*, 2021(1), 3663315
- [3] Ji, J., Wang, Q., Huang, T., Wang, Z., He, P., Guo, C., ... & Wang, H. (2021). Efficacy of low-dose trimethoprim/sulfamethoxazole for the treatment of pneumocystis jirovecii pneumonia in deceased donor kidney recipients. *Infection and Drug Resistance*, 4913-4920.
- [4] Qian, Y., Shi, C., Cheng, C., Liao, D., Liu, J., & Chen, G. T. (2023). Ginger polysaccharide UGP1 suppressed human colon cancer growth via p53, Bax/Bcl-2, caspase-3 pathways and immunomodulation. *Food Science and Human Wellness*, 12(2), 467-476
- [5] Haseeb, A., Abourehab, M. A., Almalki, W. A., Almontashri, A. M., Bajawi, S. A., Aljoaid, A. M., ... & Faidah, H. S. (2022). Trimethoprim-sulfamethoxazole (bactrim) dose optimization in *Pneumocystis jirovecii* pneumonia (PCP) management: a systematic review. *International Journal of Environmental Research and Public Health*, 19(5), 2833.
- [6] Ren, X., Huang, J., He, J., Bai, Z., & Wang, Z. (2024). *Salmonella typhimurium* infection after lingual mucosa graft ureteroplasty: a case report and review of literature. *BMC Infectious Diseases*, 24(1), 13

- [7] Lamichhane, B., Mawad, A. M., Saleh, M., Kelley, W. G., Harrington, P. J., Lovestad, C. W., ... & Helmy, Y. A. (2024). Salmonellosis: an overview of epidemiology, pathogenesis, and innovative approaches to mitigate the antimicrobial resistant infections. *Antibiotics*, 13(1), 76.
- [8] Mkgangara, M. (2023). Prevention and control of human Salmonella enterica infections: An implication in food safety. *International Journal of Food Science*, 2023(1), 8899596.
- [9] Rahman, K. T., & Butzin, N. C. (2024). Counter-on-chip for bacterial cell quantification, growth, and live-dead estimations. *Scientific Reports*, 14(1), 782.
- [10] Mkgangara, M. (2023). Prevention and control of human Salmonella enterica infections: An implication in food safety. *International Journal of Food Science*, 2023(1), 8899596.
- [11] Dissanayake, K. G. C., Waliwita, W. A. L. C., & Liyanage, R. P. (2020). A review on medicinal uses of Zingiber officinale (ginger). *International Journal of Health Sciences and Research*, 10(6), 142-148.
- [12] Ma, R. H., Ni, Z. J., Zhu, Y. Y., Thakur, K., Zhang, F., Zhang, Y. Y., ... & Wei, Z. J. (2021). A recent update on the multifaceted health benefits associated with ginger and its bioactive components. *Food & Function*, 12(2), 519-542.
- [13] Vashist, H., & Jindal, A. (2012). Antimicrobial activities of medicinal plants–Review. *Int J Res Pharm Biomed Sci*, 3(1), 222-230.
- [14] Deguale, A. (2024). *Phytochemical Analysis, Antioxidant and Antibacterial Activities of Ginger (Zingiber Officinale)* (Doctoral dissertation).
- [15] Shenbagavalli, S., Prabhu, T., Shalini, K., Rajangam, J., Rubika, R., & Dhanushkodi, V. (2024). Phytochemical analysis and identification of different metabolites profiling in oil extracted from ginger (Zingiber officinale Rosc.) using gas chromatography and mass spectroscopy technique. *Annals of Phytomedicine*, 13(1), 1193-1198.
- [16] Sheet, A. H., & AL-Azawi, A. H. (2022). Antibacterial Activity of Leaves Extract Against Laurus Nobilis Pseudomonas aeruginosa. *Indian Journal of Ecology*.
- [17] Lu, Y., Qin, L., Mao, Y., Lnong, X., Wei, Q., Su, J., & Zhao, L. (2024). Antibacterial activity of a polysaccharide isolated from litchi (Litchi chinensis Sonn.) pericarp against Staphylococcus aureus and the mechanism investigation. *International Journal of Biological Macromolecules*, 279, 134788.

- [18] Kamal, G. M., Nazi, N., Sabir, A., Saqib, M., Zhang, X., Jiang, B., ... & Murtaza, S. (2023). Yield and chemical composition of ginger essential oils as affected by inter-varietal variation and drying treatments of rhizome. *Separations*, 10(3), 186.
- [19] Odo, J. I. (2023). ANTIBACTERIAL ACTIVITIES OF THREE COMMONLY USED SPICES; GARLIC (ALLIUM MOLLE), GINGER (ZINGIBER OFFICINALE), AND TURMERIC (CURCUMA LONGA) EXTRACTS ON BACTERIAL ISOLATES FROM SPOILED TOMATOES (LYCOPERSICON ESCULATUM). *IPHO-Journal of Advance Research in Pharmacy & Biological Science [ISSN 3050-9181]*, 1(09), 01-09.
- [20] Singh, A. A., Naaz, Z. T., Rakaseta, E., Perera, M., Singh, V., Cheung, W., ... & Nath, S. (2023). Antimicrobial activity of selected plant extracts against common food borne pathogenic bacteria. *Food and Humanity*, 1, 64-70.
- [21] Gunasena, M. T., Rafi, A., Mohd Zobir, S. A., Hussein, M. Z., Ali, A., Kutawa, A. B., ... & Ahmad, K. (2022). Phytochemicals profiling, antimicrobial activity and mechanism of action of essential oil extracted from ginger (*Zingiber officinale* Roscoe cv. Bentong) against *Burkholderia glumae* causative agent of bacterial panicle blight disease of rice. *Plants*, 11(11), 1466.
- [22] Günaydın, E., Goncagül, G., Güceyü, Ç., & Kardoğan, Ö. (2021). What about the antibacterial activity of fresh ginger juice (*zingiber officinale*). *J Adv Med Res*, 163-72.
- [23] Oyinlola, K. A., Ogunleye, G. E., Balogun, A. I., & Joseph, O. (2024). Comparative study: Garlic, ginger and turmeric as natural antimicrobials and bioactives. *South African Journal of Science*, 120(1-2), 1-7

البدائل الطبيعية كمضادات حيوية: دراسة مقارنة المستخلص الكحولي لجذر الزنجبيل ودواء التريميثوبريم ضد بكتيريا السالمونيلا

مستخلص البحث:

تُعتبر أمراض الأمعاء من المشاكل الصحية التي تؤدي إلى ظهور ميكروبات ضارة مقاومة للعديد من الأدوية، ويشكل استخدام المواد الطبيعية تحديًا كبيرًا للصحة، إذ تزيد من قدرتها على الحد من أعراض الأمراض المعدية المميتة. الهدف: هدفت هذه الدراسة إلى استخدام نباتات بديلة للموافقة عليها كأدوية للحد من قدرة البكتيريا. الطرق: تم تحضير مستخلص جذر الزنجبيل واختباره باستخدام تقنية التركيز المثبط الأدنى (MIC). وتم تقييم نشاطه المثبط ضد أربع عزلات بكتيرية باستخدام أطباق أجار. وتمت مقارنة تأثير المستخلص بتأثير مضاد حيوي قياسي (تريميثوبريم). بالإضافة إلى ذلك، تم إجراء تحليل كيميائي لتحديد المكونات النشطة للنبات باستخدام تقنيات الكروماتوغرافيا. النتائج: أظهرت النتائج أن مستخلص الزنجبيل الكحولي قادر على إظهار نشاط مضاد للبكتيريا ممتاز، والذي تم تحديده من خلال التحقيق في التركيز المثبط الأدنى بأخذ تركيزات مختلفة (2-1024 ميكروغرام/مل). تم تحديد النشاط المضاد للأغشية الحيوية لبكتيريا السالمونيلا الأربعة، وأظهرت النتائج أن التنشيط بالمنطقة تراوح بين 20 و 26 مم لمستخلص جذور الزنجبيل مقارنة بدواء تريميثوبريم. الاستنتاجات: يُمثل مستخلص الزنجبيل الكحولي بديلاً مناسباً للمضادات الحيوية الكيميائية لمكافحة بكتيريا السالمونيلا.

الكلمات المفتاحية: جذر الزنجبيل، دواء التريميثوبريم، التركيز المثبط الأدنى، التركيز القاتل الأدنى، كروماتوغرافيا الغاز-مطيافية الكتلة