INTERNATIONAL JOURNAL OF PHARMACEUTICS RESEARCH
ISSN: 3106-7727 |3106-7719
Volume 2, Issue 2, 2025

A REVIEW ON THE ANTIMICROBIAL AND ANTIOXIDANT EFFECTS OF GINGER

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Keywords
Ginger, antimicrobial, antioxidant, bioactive compounds, oxidative stress, natural remedies

Article History
Received: 19 April, 2025
Accepted: 15 May, 2025
Published: 30 June, 2025

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Abstract
This study, conducted at AIMS Muzaffarabad, AJK (April–September 2024), compared the effects of 12 mg versus 15 mg bupivacaine on maternal hypotension following spinal anesthesia in elective cesarean sections. Hypotension occurred in 16% of patients in the 12 mg group (Group A) and 24% in the 15 mg group (Group B). Other complications, including bradycardia, respiratory depression, nausea/vomiting, and patient discomfort, were also assessed. The study concluded that 12 mg of bupivacaine is associated with a lower incidence of maternal hypotension and may reduce the need for corrective interventions such as vasopressors and fluid overload, making it a safer option for spinal anesthesia in cesarean deliveries.

INTRODUCTION

Zingiber officinale are the rhizomes of the aromatic plant Roscoe (ginger) belong to the Zingiberaceae family and are used as spices. Because galangal is rich in bioactive ingredients, it is used as a medicine to treat a variety of conditions, including rheumatoid arthritis, inflammatory bowel illnesses, diabetes, ulcers, stomachaches, colds, diarrhea, and swelling in the abdomen. It is most commonly used in Far Eastern countries. The bioactive components of ginger are widely known for their antibacterial, antifungal, and antioxidant properties. It is frequently utilized for its anti-inflammatory and anti-tumorigenic effects in addition to assisting capabilities of cholesterol reducing and digestive difficulties.(1)

The chemical components in spices give them their antibacterial and antioxidant characteristics, which are the source of their therapeutic qualities. The kind and quantity of the spice, as well as the diversity and density of microorganisms, all affect antimicrobial action. Phenolic and terpenoid compounds containing hydroxyl groups, which are responsible for the inhibitory action by breaking the phospholipid membrane of the cell membrane, are mostly accountable for the antimicrobial activity. All the content of the cell thus leaks out due to the raised permeability of the cell membrane. Spices perform satisfactorily in any phase of microbial growth like prolonging the lag phase or reducing the growth rate in exponential phase and the overall reduction in the number of cells.(2)

The Zingiberaceae family include numerous perennial herbs that are monocotyledonous. This plant, which belongs to more than 1,200 species and over 50 genera, is commonly grown in tropical and subtropical regions. Ginger has been used widely as a spice, flavoring agent, and folk cure. Investigations into the pharmacological properties of ginger have shown that it possesses anti-inflammatory, antioxidant, gastrointestinal modulating, anticancer, antivomiting, neuroprotective, anti-inflammatory, cardiovascular protector, antiobesity, antinausea, anti-emetic, protective effects against respiratory disorders, and analgesic properties. One ginger derivative that is used in a variety of goods, including food, medicine, and cosmetics, is ginger essential oil (GEO). Numerous research have also documented the diverse biological actions of GEO, including its antibacterial, antioxidant, analgesic, bronchodilator, anti-ulcer, anticancer, and immunomodulatory properties.(3)

Indigenous to Southeast Asia, ginger (Zingiber officinale) belongs to the Zingiberaceae family of plants. Asia's indigenous tribes, mainly in China and India, have been eating ginger for centuries in all sorts of preparations. It is a spice and sweetener in local foods as well as a medicinal herb for a variety of purposes. More precisely, ginger is believed to possess medicinal value in traditional Chinese, Indian, and Ayurvedic medicine. Due to its expectorant quality, which assists in breaking up and expelling mucus, it is administered as a cough relief drug. Furthermore, ginger aids digestion, eases pain, and cures nausea, vomiting, and poisoning.(4)

Up to this point, studies have demonstrated that ginger is beneficial in the prophylaxis and treatment of gastrointestinal, cardiovascular, pulmonary, and neurological diseases. It is also anti-inflammatory, antioxidant, and anticancer. The edible part of the plant is referred to as rhizome. The nutraceutical potential of ginger is attributed to the bioactive chemicals found in the rhizome, including gingerols (GNs), shogaols (SGs), paradols, and zingiberene.(5)

Dry ginger powder is also known as Sonth in Hindi, Sonti in Telugu, and Soonth in Gujarati. Gingerols are the active compound present in fresh ginger and are the major phenolic substances of ginger. Active phytochemicals like shogaols, paradols, zerumbone, zingerone, gingerols, and 1-dehydro-(10) gingerdione are abundant in the other significant polyphenols. Ginger can be used to make shogaols by heating it or storing it for a long time. Shohaols can be formed from paradols by hydrogenation. In addition to these, lipids, organic acids, and polysaccharides are all included in the raw fiber of ginger. The biological actions of ginger, including its anti-inflammatory, anticancer, antibacterial, and antioxidant properties, are significantly linked to its active components. Thus, the primary source of 6-SG, the most well-known dehydration product, is dried ginger rhizome.(6)

The search for and assessment of natural antioxidants and antimicrobials has received a lot of attention lately. Because of their natural origins, which offer medicinal benefits with little adverse effects, plants are used. Compared to the medications that are currently on the market, which may have negative consequences after extended usage, it is also a safer option. The ginger plant is a herbaceous perennial with a yearly growth of pseudo-stem that can withstand temperatures exceeding two years. The primary part of the ginger plant that is eaten is the aromatic and pungent rhizome, or the horizontal stem where the roots develop. In order to improve lives and livelihoods via equitable and sustainable use of natural resources, Z. officinale is a naturally occurring medicinal plant that was used in this study to determine its antibacterial and antioxidant properties.(7)

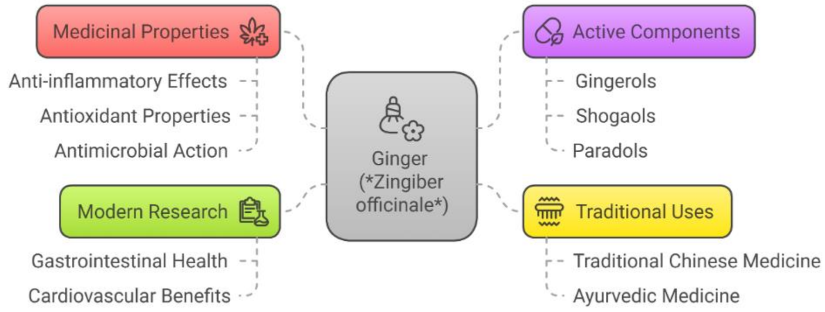

Figure 1: Gingers multifaceted roles and benefits

Around the world, ginger is used as a spice and flavoring. It possesses a number of well-known health benefits, including pharmacological activity, antioxidant, antibacterial, anti-inflammatory, anti-nociceptive, anti-mutagenic, and hepatoprotective activities.(8) Terpenes and phenolic compounds are two of the major active constituents of ginger. Some of the phenolic constituents of ginger include gingerols, shogaols, and paradols. Gingerols, including 6-gingerol, 8-gingerol, and 10-gingerol, are the most common phenolic chemicals present in fresh ginger.Matching shogaols could be produced from the gingerols by heat treatment or long-term preservation. These shogaols could become paradols after hydrogenation.(9)

The antioxidant action of ginger is attributed to its bioactive constituents, including zingiberene, zingerone, shogaols, and gingerols. Ginger's rhizome is frequently used in medicine to treat a wide range of conditions, such as diabetes, rheumatoid arthritis, diarrhea, gastrointestinal ulcers, migraine headaches, certain cancers, and some respiratory illnesses. Of the herbs, Zingiber officinale is one of the most common. Certain components of this plant can also function as antioxidants, which are chemicals that can either slow down or increase the body's natural oxidation processes. The current study was carried out to demonstrate the biochemical profile, antioxidant activity, and antimicrobial efficacy of ginger against specific oral microbes, with the aim of encouraging its use in households by highlighting its biochemical components, antioxidant, and antibacterial properties.(10)

Due in large part to its abundance of phenolic acids and flavonoids—secondary plant metabolites noted for their antibacterial and antioxidant properties—ginger is also acknowledged for its antioxidant activity. Antioxidants aid in preventing cellular damage and slowing down the aging process by scavenging dangerous free radicals. Antioxidants also stop lipid oxidation, which keeps food from spoiling or going rancid. Phenylalanine is the source of flavonoids, which have attracted attention due to their strong antioxidant activity and ability to effectively scavenge free radicals, as demonstrated by both in vitro and in vivo research. (11) These substances have been associated with a lower risk of cardiovascular disease, anti-cancer properties by inducing apoptosis through p53 activation, and protection against age-related illnesses. Consequently, ginger is a good natural substitute for chemical food preservatives due to its antioxidant and antibacterial properties. Further driving the demand for more ecologically friendly food preservatives is the encouragement by governments around the world, particularly in the European Union, for producing industries to adopt greener methods. An efficient extraction process is essential to effectively using the antibacterial and antioxidant components found in ginger. There are restrictions on solvent volume and extraction time with traditional extraction techniques including shaking extraction, Soxhlet extraction, and organic solvent extraction, which are not good for the environment.(12)

Table 1: Major Bioactive Compounds in Ginger and Their Pharmacological Activities

Compound	Chemical Nature	Pharmacological Activity	Mechanism of Action
Gingerol	Phenolic compound	Antioxidant, Anti-inflammatory, Antimicrobial	Scavenges free radicals, inhibits prostaglandin synthesis
Shogaol	Dehydration product	Antioxidant, Antitumor, Neuroprotective	Enhances antioxidant enzymes, induces apoptosis
Zingiberene	Sesquiterpene	Antibacterial, Anti-inflammatory	Disrupts microbial membranes, inhibits cytokines
Zingerone	Phenolic aldehyde	Antioxidant, Antidiarrheal, Anticancer	Inhibits lipid peroxidation, modulates gene expression
Paradol	Phenolic ketone	Antioxidant, Antitumor	Induces ROS-mediated apoptosis in cancer cells
β-Bisabolene	Sesquiterpene	Antibacterial, Gastroprotective	Inhibits microbial growth, protects gastric mucosa

As far as we are aware, earlier research has focused mostly on the antimicrobial properties and volatile makeup of essential oils that were isolated from fresh ginger samples. The assessment of the physicochemical properties, antioxidant activity, and antibacterial potential of the extract made from dried ginger utilizing ultrasonication to boost extraction efficiency in comparison to conventional extraction methods, therefore, constitutes the uniqueness of this work. Along with examining the connections between the sonicated ginger extract's antibacterial activity and its phenolic content, antioxidant activity, and volatile components.(13)

Additionally, ginger is said to be a potent antioxidant that may reduce the production of free radicals. However, because of its antioxidant properties and protective qualities, ginger also possesses the potential to be used as an insecticide, antibacterial, anticancer, antidiabetic, and for other bioactivities. Recent research on ginger rhizome has demonstrated that it can improve growth performance in lab animals without having a major detrimental effect on dosage.(14) With a broad metabolite spectrum, ginger essential oils are among the natural items that may offer an alternative class of natural antimicrobials, paving the way for the development of new and more potent molecules that can control plant infections. It is increasingly evident that these natural materials, with their low toxicity, economic viability, and biological and antibacterial properties, might impact contemporary agrochemical solutions. They are also well known for being biodegradable, widely accepted by many societies, and possessing antibacterial, antiviral, and antifungal properties in addition to acting as insect repellents. It is therefore a novel defense against pathogen attacks on plants.(15)

Antimicrobial activity of Ginger:

Phenolic constituents including eugenol, shogaols, zingerone, gingerdiols, and gingerols, together with the synergistic action with other secondary metabolites including β-sesquiphellandrene, cis-caryophyllene, zingiberene, α-farnesene, and α- and β-bisabolene account for most antimicrobial activity represented by ginger essential oil, oleoresins, and extracts. Most of the compounds are non-aqueous; thus aqueous extracts have lower activity compared to oleoresins, essential oils, and organic extracts. Thus, the ginger essential oil has been described to have high fungicidal and antibacterial activities owing to its high constituent of eugenol. Most major compounds representing antimicrobial activity of the fresh ginger essential oil include geranial, α-zingiberene, (E, E)-α-farnesene, neral, ar-curcumene, and β-sesquiphellandrene, while eugenol and zingerone are described as the primary constituents in oleoresins. Antimicrobial activity of ginger has been attributed further by some authors to the processing treatment involved. For instance, fresh ginger essential oil has a higher content of oxygenated compounds (29.2%) such as geranial, 1,8-

cineole, neral, borneol, and α-terpineol compared to dried ginger essential oil, the percentage of which is low (14.4%) and thereby exhibits minimal antibacterial and antifungal activity.(16)

Table 2: Antimicrobial Activity of Ginger Extracts Against Microorganisms

Microorganism	Type	Extract Type	Zone of Inhibition (mm)	Method Used
Staphylococcus aureus	Gram-positive	Ethanolic	18 mm	Agar Well / Disc Diffusion
Enterococcus faecalis	Gram-positive	Ethanolic	16 mm	Agar Well / Disc Diffusion
Pseudomonas aeruginosa	Gram-negative	Ethanolic	15 mm	Agar Well / Disc Diffusion
Escherichia coli	Gram-negative	Ethanolic	17 mm	Agar Well / Disc Diffusion
Candida albicans	Fungus	Ethanolic	20 mm	Agar Well / Disc Diffusion

Mechanism of action:

Ginger (*Zingiber officinale*) has shown antimicrobial properties due to its bioactive compounds, particularly gingerols, shogaols, and paradols. These compounds exhibit antimicrobial activity through several mechanisms:

Cell Membrane Disruption: Ginger's bioactive compounds, especially gingerols, can interact with the lipid bilayer of microbial cell membranes, increasing membrane permeability and causing cell leakage. This disrupts the structural integrity of the cell, leading to cell lysis and death.(17)

Inhibition of Enzyme Activity: Some ginger compounds inhibit key enzymes involved in microbial metabolism. For example, 6-gingerol and 6-shogaol can interfere with ATP production by inhibiting ATPase activity, leading to energy depletion and impaired microbial growth.(18)

DNA Damage: Ginger's bioactive compounds can cause damage to microbial DNA, particularly through oxidative stress. Compounds in ginger induce the production of reactive oxygen species (ROS), which can cause DNA fragmentation and ultimately kill the microbes.(19)

Protein Synthesis Inhibition: Ginger compounds may interfere with microbial protein synthesis, especially at the ribosomal level, which prevents essential proteins from being formed, halting bacterial growth.

Anti-Biofilm Activity: Biofilms protect bacteria from the effects of antimicrobial agents. Ginger's active compounds, particularly 6-shogaol, can disrupt biofilm formation or break down existing biofilms, making bacteria more vulnerable to immune responses or antibiotics.(20)

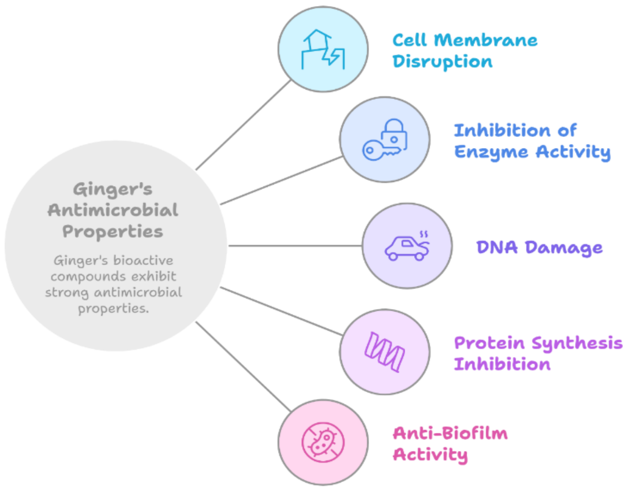

Figure 2: Unveiling Gingers antimicrobial power

Determination of Antimicrobial Activity:

Microorganisms

Five bacteria were tested for the antimicrobial properties of extracts made using ethanol and water. Gram-positive bacteria are represented by S. aureus ATCC 25923 and E. faecalis ATCC 29212, while P. aeroginosa (ATCC 27853) and E. Coli ATCC 25922 were Gram-negative bacteria are represented by this. The antibacterial and antioxidant properties were also assessed using the fungus Candida albicans ATCC 10231.

Agar-well and Disc Diffusion Method

The antimicrobial activity was assessed using the agar-well and disc diffusion methods. For 24 hours, bacterial cultures were cultivated at 37°C, and for 48 hours, Candida albicans was cultivated at 25°C. We adjusted suspensions using the McFarland 0.5 standard. Mueller-Hinton Agar (MHA) was applied to 100 µl of microbial cultures in Petri plates. On MHA, a 6-mm agarwell is opened or a disc made with paper (Watmann no. 4). Wells or discs were infected with extracts (15 µL). Plates were subsequently incubated for 24 to 48 hours. The inhibitory zone's diameter was assessed following incubation.(2)

Antioxidant activity of Ginger:

Ginger CO_2 extract contains a high amount of polyphenols. It expressed a greatly good DPPH scavenging and lowered its reducing capacity. The extract is able to serve as an antioxidant at an earlier point in fat oxidation. The antioxidant activity of ginger extract was as good as that of BHT in inhibiting lipid peroxidation both at 37 C, and at a high temperature of 80 C. Most suppressed was the formation stage of secondary products of auto-oxidation of fats. The ginger extract also inhibited the hydroxyl radicals, more than that of quercetin at both temperatures used in the study. In the conditions of carried-out experiments, the polyphenols of ginger extract also proved to have greater chelatoforming ability as far as Fe^{3+} is concerned, and thus preventing initiation of hydroxyl radicals known inducers of lipid peroxidation.(21)

Table 3: Antioxidant Activity of Ginger Extract Compared to Standards

Sample	Test Performed	Activity Observed	Temperature Conditions	Reference Control
Ginger CO_2 Extract	DPPH Radical Scavenging Assay	Strong radical scavenging activity	Room Temp / 80°C	BHT, Quercetin
Ginger CO_2 Extract	Lipid Peroxidation Inhibition	Inhibits secondary product formation	37°C and 80°C	BHT
Ginger CO_2 Extract	Hydroxyl Radical Inhibition	Higher than Quercetin	Both temperatures	Quercetin
Ginger CO_2 Extract	Chelation of Fe^{3+} Ions	High chelating capacity, prevents oxidation	Room Temp	-

1. Free Radical Scavenging

- One of the major mechanisms by which ginger functions as an antioxidant is by trapping free radicals. Free radicals are extremely reactive molecules that have the ability to destroy cellular components such as lipids, proteins, and DNA. Antioxidant compounds in ginger trap free radicals by directly donating electrons, thus stabilizing them and inhibiting further cellular destruction.

- **Gingerol:** The major bioactive compound in fresh ginger, has been shown to act as a potent free radical scavenger. It is structurally similar to compounds like curcumin (found in turmeric), which are known for their antioxidant activity. Gingerol's chemical structure allows it to interact with and neutralize free radicals, reducing oxidative damage.

2. Modulation of Antioxidant Enzyme Activity

Ginger enhances the body's **endogenous antioxidant defense system** by influencing the activity of certain antioxidant enzymes, which play a crucial role in neutralizing oxidative stress. Some key enzymes include:

- **Superoxide dismutase (SOD)**: This enzyme converts superoxide radicals (a type of free radical) into less harmful molecules.
- **Catalase**: This enzyme breaks down hydrogen peroxide, another reactive oxygen species (ROS), into water and oxygen.
- **Glutathione peroxidase**: This enzyme helps detoxify free radicals by using glutathione, a potent antioxidant, to reduce peroxides and prevent oxidative damage.

3. Inhibition of Inflammatory Pathways

Inflammation and oxidative stress are closely related, and inflammation often exacerbates oxidative damage. Ginger's antioxidant effects are complemented by its **anti-inflammatory properties**, which help reduce the oxidative burden in the body.

- **Gingerol and shogaol** have been shown to inhibit pro-inflammatory molecules like TNF-α (Tumor Necrosis Factor-alpha), IL-6 (Interleukin-6), and COX-2 (Cyclooxygenase-2), which are involved in the inflammatory response. By reducing the production of these molecules, ginger can help lower inflammation-induced oxidative stress.(22)

Phytochemical Composition and Antioxidant Activity of Ginger:

Ginger (Zingiber officinale) is a rich source of bioactive compounds for its antioxidant activity. Among such compounds, phenolic acids pyrogallol, p-hydroxybenzoic acid, ferulic acid, and p-coumaric acid are particularly mentioned. The phenolic compounds can scavenge free radicals, extremely reactive molecules with the potential to cause oxidative damage to cells, lipids, proteins, and DNA. Through scavenging these free radicals, such compounds contribute to alleviating oxidative stress, a state that has been associated with chronic diseases such as cancer, cardiovascular disease, and neurodegenerative diseases.(23)

It has just been reported that antioxidant activity of ginger is primarily based on the presence of such phenolic compounds, among other bioactive molecules such as gingerols and shogaols. For example, gingerols, the active compounds present in raw ginger, have been reported to exhibit effective antioxidant activities through direct interaction with and neutralization of free radicals. According to a study by Rahmani et al. (2018), ginger extracts with high gingerol content have been seen to enhance the antioxidant defense systems of the body by promoting the activity of such enzymes as superoxide dismutase (SOD) and catalase, which are responsible for detoxifying the reactive oxygen species (ROS).(24) Besides, it has been observed that the process of extraction is significant in the antioxidant activity of ginger. Ethanolic extracts of ginger were observed to exhibit greater antioxidant activity compared to aqueous extracts. This difference in activity is attributed to the enhanced solubility of phenolic compounds in ethanol, leading to enhanced extraction and bioavailability of these antioxidants. A study by Ahmad et al. (2019) showed that ginger ethanol extracts had stronger free radical scavenging activities and higher lipid peroxidation inhibitory effects than water extracts. This underlines the importance of the extraction method in determining the efficacy of ginger's bioactive compounds and the need for standardized methodology to achieve the best ginger therapeutic potential.(25)

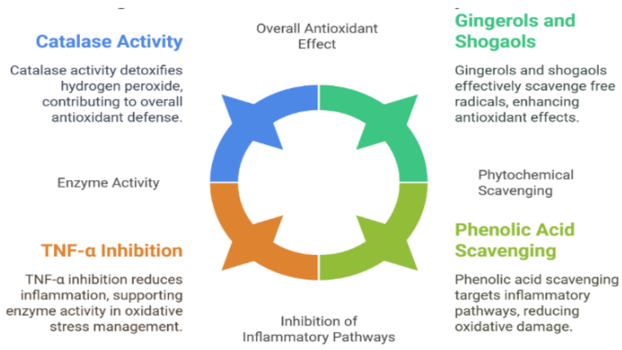

Figure 3: Gingers antioxidant and anti-inflammatory activities

Determination of Antioxidant Activity:

DPPH Radical Scavenging Assay

Blois (1958) and Khalaf et al. (2008) developed a spectrophotometric approach to measure radical scavenging activity.Three iterations of the tests were conducted. The positive control in this study was ascorbic acid.

Total Antioxidant Status assay

The extracts were examined in terms of total antioxidant status (TAS) using a colorimetric technique that Erel (2004) devised. This process uses the Fenton reaction to create hydroxyl radicals, and it reacts with the colourless substrate o-dianisidine to produce brilliant yellowish-brown dianisyl radicals. Micromolar Trolox equivalents per litre (μmol Trolox Eq/L) were used to express the results.(2)

CONCLUSION:

It is concluded that the antimicrobial and antioxidant properties of ginger (Zingiber officinale) underscore its significant potential as a natural therapeutic agent. The bioactive compounds in ginger, such as gingerol and shogaol, exhibit notable antimicrobial effects against a range of pathogens, offering promising alternatives to conventional antibiotics, particularly in the face of rising antimicrobial resistance. Ginger's (Zingiber officinale) antibacterial and antioxidant properties demonstrate its dual therapeutic promise as a natural cure for illness prevention and health promotion.

Ginger's bioactive components, including gingerol, shogaol, and paradol, have broad-spectrum antibacterial qualities that target a range of bacterial, fungal, and viral pathogens, according to a wealth of evidence from in vitro and in vivo investigations. According to these results, ginger may be a useful supplement or substitute for traditional antibiotics, particularly in light of the rise in antibiotic resistance.

Acknowledgments:
We would like to express our sincere gratitude to the faculty and administration staff of Superior University, Lahore, for their invaluable support and guidance throughout the process of preparing this research paper.

Originality and submission Status of Manuscript:
The work done and material used in this manuscript has not been previously published and is not being concurrently submitted elsewhere.

Ethical Approval:
Our study was approved by the Ethical Board of Academic and Research Unit, the Superior University Lahore.

Funding Source:
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Conflicting Interest:
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

BACKGROUND:
Ginger (*Zingiber officinale*), a widely used medicinal and culinary herb, has gained scientific interest for its bioactive compounds, such as gingerols and shogaols, which exhibit antimicrobial and antioxidant properties. With the rise of antimicrobial resistance (AMR) and the global burden of oxidative stress-related diseases, natural alternatives like ginger have become increasingly relevant. This review explores ginger's dual role as an antimicrobial and antioxidant agent, emphasizing its mechanisms, therapeutic potential, and the need for further research to optimize its use.

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