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# The Golden Root: A Pharmacological Exploration of Ginger's Health Benefits

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**Abstract**

Ginger (*Zingiber officinale*), a widely used spice and medicinal plant, has garnered significant attention for its diverse pharmacological properties. This review explores the therapeutic potential of ginger, focusing on its bioactive constituents such as gingerols, shogaols, and paradols, which are responsible for its wide range of pharmacological activities. Ginger exhibits potent anti-inflammatory, antioxidant, antimicrobial, anticancer, anti-diabetic, and cardiovascular-protective effects. Additionally, it has demonstrated efficacy in managing gastrointestinal disorders, reducing nausea, and alleviating pain in conditions like osteoarthritis. Emerging studies also highlight its neuroprotective and immunomodulatory properties, making it a promising candidate for addressing various chronic and acute diseases. This review consolidates current research on ginger's pharmacological effects, underlying mechanisms, and potential therapeutic applications, providing a comprehensive understanding for future studies and clinical applications.

**Keywords**: Ginger (*Zingiber officinale*), Pharmacological activity, Bioactive compounds, Therapeutic potential, Medicinal plant

## 1. INTRODUCTION

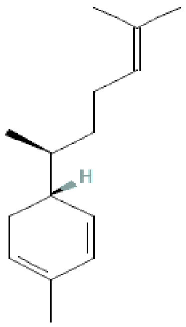
Ginger (*Zingiber officinale*), a perennial herbaceous plant of the Zingiberaceae family, is globally cherished for its culinary and medicinal applications (Begum et al., 2018). Known for its pseudo-trunk and erect stature, ginger grows to a height of 30 cm to 1 m and features lanceolate leaves measuring 15-23 cm in length and 8-15 mm in width. The plant's underground rhizomes are its most valued part, characterized by their pale-yellow interior, irregular branching, and fibrous texture. These rhizomes are capable of regenerating shoots, making them highly sustainable when cultivated (Setyawan, 2014).

In Southeast Asia, ginger has long been used in traditional medicine for treating digestive issues, sore throats, coughs, and fevers (Mao et al., 2019). However, traditional soil-based cultivation methods, including shifting cultivation, often result in land degradation. Modern methods like fertigation have shown promise in improving yields and reducing environmental impacts (Shuhaimi et al., 2016). Despite its many benefits, ginger deteriorates rapidly after harvest due to dehydration, microbial invasion, and aging, necessitating efficient post-harvest management techniques to preserve its quality and economic value (Kaushal et al., 2017).

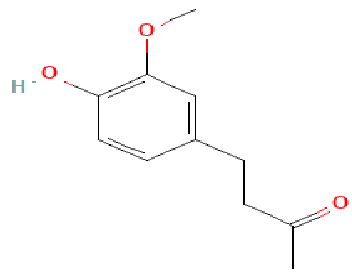
Ginger's chemical composition includes both volatile and non-volatile oils, contributing to its therapeutic properties. Volatile oils consist mainly of sesquiterpenes (e.g., zingiberene) and monoterpenes (e.g., cineole, geraniol), which are responsible for its characteristic aroma. The non-volatile oils contain phenolic compounds, such as gingerols, shogaols, and zingerone, which exhibit antioxidant, anti-inflammatory, and immunomodulatory effects (Wohlmuth et al., 2005; Mahboubi, 2019). Gingerols in fresh ginger dehydrate into shogaols during drying, enhancing their medicinal potency (Munda et al., 2018).

Therapeutically, ginger has demonstrated various health benefits, including antioxidant and anti-inflammatory effects, cardiovascular health improvements, and nausea alleviation. Gingerol and shogaol help regulate lipid levels, inhibit vascular smooth muscle cell proliferation, and reduce platelet aggregation (Jain et al., 2016; Wang et al., 2018).

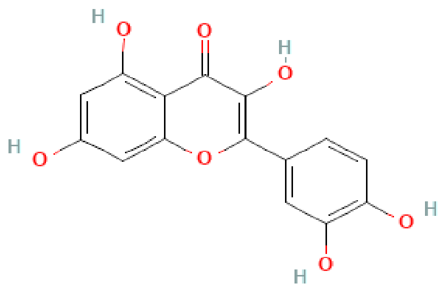
Ginger is also recognized for its antimicrobial and antiviral properties, further solidifying its role as an immune booster (Ji et al., 2017). Globally, ginger is widely used as a spice and natural remedy, making it a vital component of traditional and modern medicine (Menon et al., 2021).



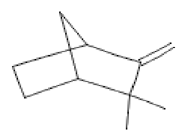
Zingiberene



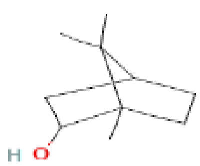
Zingerone



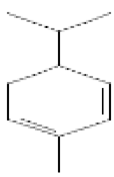
Quercetin



Camphene



Borneol



Phellandrene

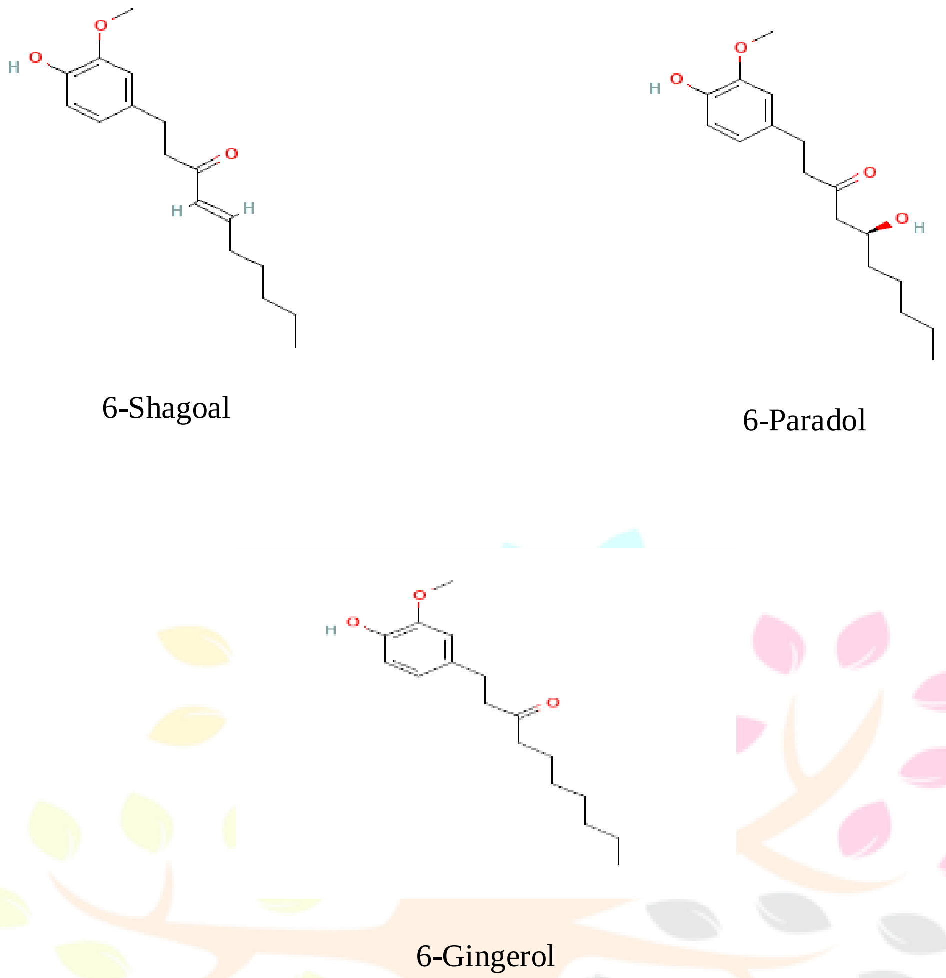



**Figure 1: Structures of the important chemical constituents present in the ginger**

The increasing prevalence of chronic diseases, coupled with growing interest in natural and complementary therapies, has amplified research on ginger's medicinal potential. Scientific studies have validated many traditional uses of ginger, particularly in alleviating gastrointestinal discomfort, reducing nausea, and managing pain. Moreover, emerging evidence highlights ginger's potential in addressing complex conditions such as cardiovascular diseases, diabetes, neurodegenerative disorders, and cancer. Despite its extensive use, there remains a need to comprehensively understand the mechanisms underpinning its therapeutic effects and to explore its clinical efficacy in greater detail. This review aims to provide a holistic overview of the pharmacological activities of ginger, with a focus on its bioactive constituents, mechanisms of action, and therapeutic implications across various disease conditions.

## 2. PHARMACOLOGICAL ACTIVITIES OF GINGER

The pharmacological activities of ginger are attributed to its rich profile of bioactive compounds, including gingerols, shogaols, zingerone, and zingiberene. These compounds exhibit diverse therapeutic properties, making ginger a versatile medicinal plant with applications in managing inflammation, oxidative stress, infections, cancer, and various metabolic disorders. The image (Figure 2) highlights the diverse pharmacological properties of ginger, showcasing its potential as a therapeutic agent.

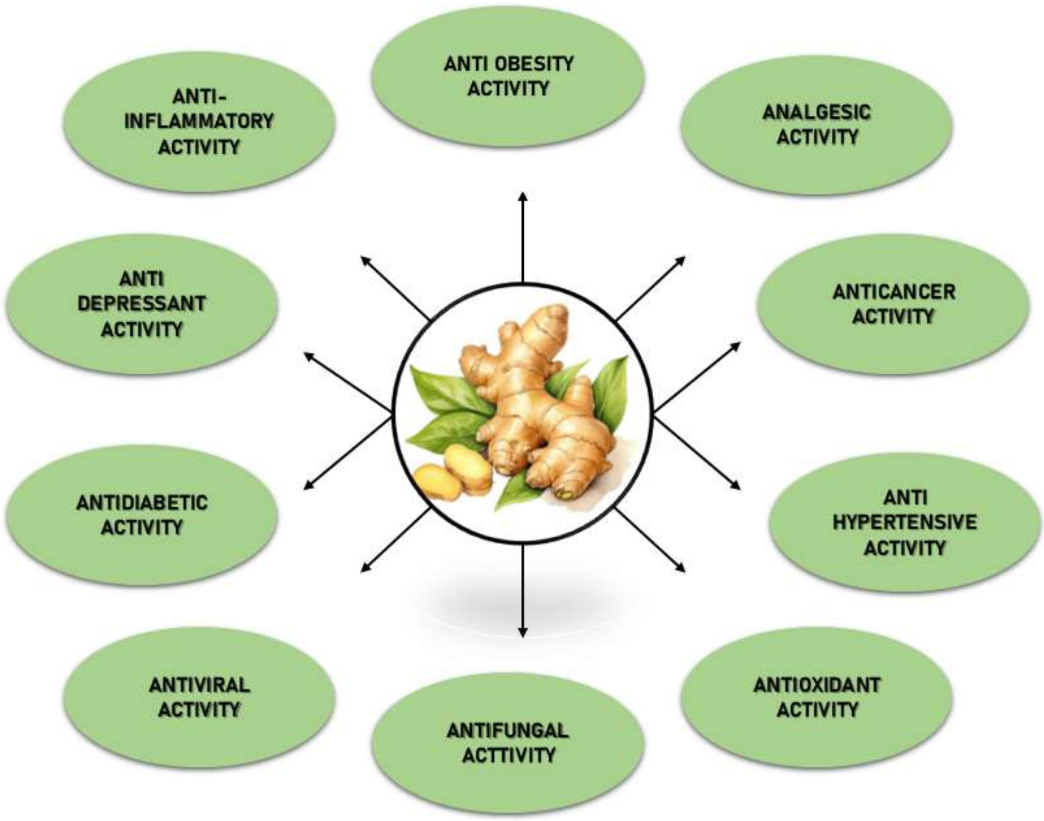
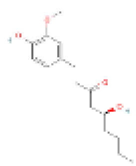
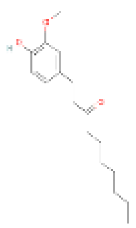
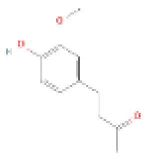
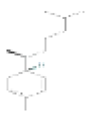



**Figure 2: Pharmacological Activities of Ginger (*Zingiber officinale*)**

**Table 1: Phytochemical Constituents of Ginger, Their Structures, Pharmacological Activities, Screening Methods, and References**

| S. NO | Phyto Constituents | Structure | Pharmacological Activity | Pharmacological Screening Method | Reference |
|---|---|---|---|---|---|
| 1 | 6-Gingerol |  | Anti-inflammatory activity | *In vivo* study using chlorpyrifos-induced oxidative damage in the brain, ovary, and uterus of rats. Markers: oxidative stress and inflammation markers like cytokines. | Abolaji et al. 2017 |
| 2 | 6-Paradol |  | antioxidant activity | *In vivo* study in acetic acid-induced ulcerative colitis in rats. Markers: Lipid peroxidation (MDA levels) and GSH activity. | Rafeeq et al., 2021 |

| | | | | | |
|---|---|---|---|---|---|
| 3 | Quercetin |  | antioxidant property | Food model testing using nanoemulsion-based edible coating on chicken breast. Markers: DPPH and ABTS free radical scavenging assays. | Noori et al., 2018 |
| 4 | 6-Shagoal |  | anticancer properties | *In vitro* study on UVB radiation-mediated inflammation in human epidermal keratinocytes (*HaCaT* cells). Markers: ROS levels, NrF2 signaling. | Chen et al., 2019 |
| 5 | Borneol |  | antibacterial activity | *In vitro* antibacterial assay using Staphylococcus aureus and Escherichia coli. **Method**: Disk diffusion and MIC determination. | Shareef et al. 2016 |
| 6 | Camphene |  | antimicrobial property | *In vitro* evaluation using bacterial and fungal pathogens. **Method**: MIC and time-kill kinetic assay. | Huang et al., 2023 |
| 7 | Zingerone |  | anticancer properties | *In vivo* study using a trinitrobenzene sulphonic acid (TNBS)-induced colitis model in mice | Hsiang et al., 2013 |
| 8 | Zingiberene |  | antibacterial properties | *In vitro* antibacterial testing and review of phytochemistry | Mohd Aleem et al., 2020 |

| | | | | | |
|---|---|---|---|---|---|
| 9 | α-Phellandrene |  | antimicrobial activity | *In vitro* antifungal study against *Penicillium cyclopium* | Zhang et al., 2017 |

MIC -Minimum Inhibitory Concentration; MDA -Malondialdehyde; GSH -Glutathione; DPPH -2,2-Diphenyl-1-picrylhydrazyl; ABTS -2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid); UVB -Ultraviolet B; TNBS -2,4,6-trinitrobenzene sulfonic acid.

### 2.1. Antioxidant Activity of Ginger

Ginger (*Zingiber officinale*) is widely recognized for its potent antioxidant properties, which are attributed to its abundance of bioactive polyphenol compounds. These compounds play a crucial role in mitigating oxidative stress (OS), which is implicated in various chronic diseases such as cancer, arthritis, diabetes, cardiovascular diseases, and neurodegenerative disorders (Sindhi et al., 2013; Singh et al., 2019).

Ginger's antioxidant capabilities stem from its bioactive compounds, particularly gingerols (6-gingerol, 8-gingerol, 10-gingerol), shogaols (6-shogaol, 8-shogaol, 10-shogaol), flavonoids, and phenolic acids (Alolga et al., 2022). These compounds neutralize free radicals (FRs), including reactive oxygen species (ROS) and reactive nitrogen species (RNS), by donating hydrogen atoms, chelating metal ions, and scavenging unpaired electrons (Mao et al., 2019).

Unneutralized free radicals can cause cellular aging and oxidative damage, contributing to diseases such as cancer, inflammatory disorders, cardiovascular diseases, and neurodegeneration (Srinivas et al., 2019; Forrester et al., 2018). Ginger mitigates oxidative damage by decreasing malondialdehyde (MDA) levels, enhancing glutathione peroxidase (GPx) activity, and inhibiting xanthine oxidase (XO) and nitric oxide (NO) production. Additionally, ginger suppresses pro-inflammatory mediators, including prostaglandin E2 (PGE2), interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), and cyclooxygenase-2 (COX-2) (Ballester et al., 2023).

Moreover, ginger reduces markers of endoplasmic reticulum stress (ERS) and decreases AKT-phosphorylation, which underscores its ability to prevent oxidative damage at the cellular level (Ballester et al., 2023). These properties render ginger an effective natural remedy for oxidative stress-related conditions, making it an essential component in therapeutic strategies.

### 2.2. Anti-Inflammatory Activity of Ginger

Ginger (*Zingiber officinale*) and its bioactive compounds exhibit potent anti-inflammatory properties, making it a promising natural remedy for various inflammation-related conditions.

Ginger targets critical inflammatory signaling pathways, including:

PI3K/Akt: Involved in cellular growth and inflammation.

NF-κB: A transcription factor regulating the expression of pro-inflammatory cytokines.

The compound 6-shogaol has been shown to inhibit these pathways, reducing tumor necrosis factor-alpha (TNF-α)-induced dysfunction and maintaining intestinal barrier integrity (Luettig et al., 2016).

Ginger suppresses the overproduction of nitric oxide (NO), interleukin-1β (IL-1β), and TNF-α while enhancing anti-inflammatory cytokine levels. This is particularly beneficial in conditions like inflammatory bowel disease and colitis (Terry et al., 2011; Mao et al., 2019).

Gingerol, a major active compound, has anti-prostaglandin effects, which alleviate pain, especially in dysmenorrhea (Jung et al., 2009).

Ginger suppresses leukotriene biosynthesis by inhibiting 5-lipoxygenase, making it effective in managing gout and allergic reactions (Chen et al., 2009).

**2.2.1. Clinical Applications:** Ginger is effective in treating colitis and intestinal dysfunctions by protecting the intestinal barrier and reducing inflammatory damage (Luettig et al., 2016). 6-shogaol has been found effective in alleviating joint inflammation associated with gout (Jeong et al., 2009). Ginger reduces allergic responses by suppressing inflammatory mediators and cytokines (Chen et al., 2009). Its anti-prostaglandin effects help in relieving pain associated with dysmenorrhea, providing a natural alternative to synthetic drugs (Jung et al., 2009).

The broad anti-inflammatory actions of ginger and its bioactive compounds (such as gingerols and shogaols) highlight its potential in managing inflammatory disorders, from digestive inflammation to joint diseases and allergies. Its ability to modulate critical pathways and inflammatory mediators makes it a versatile natural remedy.

### 2.3. Antihypertensive Activity of Ginger

Ginger (*Zingiber officinale*) exhibits significant antihypertensive properties, making it an effective natural remedy for managing high blood pressure and related cardiovascular conditions.

Bioactive compounds such as 6-shogaol and 9-gingerol help lower low-density lipoprotein (LDL) and total cholesterol levels, reducing atheroma plaque formation and improving vascular health (Azimi et al., 2016). Ginger enhances vessel elasticity and decreases inflammatory mediators, such as intercellular adhesion molecule 1 (ICAM-1), which contributes to endothelial dysfunction. This action supports the prevention of hypertension-related vascular damage (Azimi et al., 2016). Ginger's strong antioxidant activity reduces oxidative stress, a key factor in hypertension development. This includes decreasing the production of reactive oxygen species (ROS) that impair vascular function (Wang et al., 2017).

Ginger influences platelet function by modulating aggregation, which reduces the risk of blood clots and ischemic heart disease. This contributes to its protective effect against hypertension-related complications (McEwen, 2014).

**2.3.1. Clinical Evidence:** A study Randomized Controlled Trials (RCTs) on hypertensive patients with type 2 diabetes demonstrated that ginger, alongside cinnamon, cardamom, and saffron, significantly reduced blood pressure levels and improved markers of endothelial function (Azimi et al., 2016).

A systematic review of six clinical trials involving 345 participants highlighted ginger's positive effects on blood pressure, with doses of 3 grams or more per day showing significant antihypertensive effects over intervention periods of up to 8 weeks (Wang et al., 2017).

In large cohort clinical studies with 4,628 participants revealed ginger's efficacy in reducing the risk of coronary heart disease and hypertension. This supports its role in the prevention and management of chronic cardiovascular conditions (McEwen, 2014). Approximately 3 grams/day shown beneficial effects within 8 weeks or less in this trial.

Ginger's antihypertensive properties stem from its ability to regulate cholesterol, reduce inflammation, enhance vessel elasticity, and lower oxidative stress. These effects, supported by clinical and systematic studies, make ginger a promising natural option for managing high blood pressure and preventing associated cardiovascular diseases.

### 2.4. Anitobesity

Ginger (*Zingiber officinale*) has shown considerable potential in combating obesity and related metabolic disorders through its effects on energy metabolism, fat accumulation, and gut microbiota.

Research has demonstrated that ginger can prevent high-fat diet (HFD)-induced weight gain and fat accumulation. In an experimental study, mice were divided into two groups: one maintained on a normal diet (control) and the other on an HFD, with or without ginger supplementation at a dose of 500 mg/kg (w/w). Results indicated that ginger reduced triglyceride, cholesterol, and serum glucose levels, suggesting its efficacy in mitigating HFD-induced metabolic disturbances (Wang et al., 2019).

Ginger's bioactive components, such as 6-shogaol and 6-gingerol, play a pivotal role in its anti-obesity effects. These compounds activate the Peroxisome Proliferator-Activated Receptor δ (PPARδ), a crucial regulator of energy metabolism in skeletal muscle and fat pathways. This activation not only aids in weight management but also enhances exercise endurance by increasing fat breakdown in muscle tissues (Wang et al., 2020).

In mouse models, ginger supplementation demonstrated its anti-obesity benefits by altering gut microbiota. It promoted the growth of beneficial bacteria, including Bifidobacterium, which is known to support gut health and metabolic balance. This modulation of gut microbiota contributes to the prevention of obesity and its associated disorders (Wang et al., 2020).

The evidence indicates that ginger can serve as a natural therapeutic agent for managing obesity and its metabolic complications. Its effects on energy metabolism, activation of metabolic pathways, and modulation of gut microbiota highlight its potential as a multifunctional remedy for obesity-related health issues.

### 2.5. Anticancer Property of Ginger

Cancer poses a significant public health challenge worldwide and remains the second leading cause of death globally despite advancements in treatment (Siegel et al., 2013; Wang et al., 2016). Many current therapies, although effective to some extent, are associated with high toxicity, elevated costs, and limited success. Consequently, there has been an increasing focus on natural compounds derived from dietary components, such as fruits, vegetables, and teas, for their anti-cancer properties (Wang et al., 2012).

Among these, ginger (*Zingiber officinale*) and its derivatives have shown significant potential as cancer-preventive agents. These compounds exhibit multiple mechanisms of action, including the induction of apoptosis, autophagy, and autosis, halting of the cell cycle, inhibition of angiogenesis, and suppression of cancer stem cell (CSC) development and epithelial-mesenchymal transition (EMT) (Kim et al., 2017; Lechner and Stoner, 2019). Notably, these effects are tumor-specific, with minimal harm to normal cells.

Syussai ginger extract (SSHE) has demonstrated promising results in preclinical studies, effectively inhibiting the growth of pancreatic cancer cells while showing relative resistance in normal cell lines. The extract remains effective under hypoxic conditions, a challenge in conventional chemotherapy and radiotherapy (Harris, 2002; Yokoi and Fidler, 2004).

Furthermore, combining ginger with other phytochemicals like turmeric, garlic, and gelam honey has shown synergistic effects, enhancing its cancer-preventive properties. For example, ginger extract combined with gelam honey inhibits colon cancer cells through mTOR and Wnt/β-catenin pathways (Wee et al., 2015). Similarly, a mix of ginger, turmeric, and garlic exhibits a strong anti-cancer potential through cell-based studies (Vemuri et al., 2017).

These findings highlight ginger's role not only as a standalone anti-cancer agent but also as a complementary therapy that enhances the efficacy of conventional treatments and other phytochemicals.

### 2.6. Anti-Diabetic Properties of Ginger

Ginger has emerged as a promising natural agent in managing both Type 1 (T1DM) and Type 2 (T2DM) diabetes due to its bioactive secondary metabolites. It has shown significant potential in lowering blood sugar levels, improving insulin sensitivity, and reducing glycated hemoglobin (HbA1c) levels in diabetic patients. Moreover, ginger consumption can also lower LDL cholesterol, triglycerides, inflammatory markers (CRP, TNF-alpha), malondialdehyde (MDA), and apolipoprotein B (ApoB) while enhancing paraoxonase-1 (PON-1) activity (Nafiseh et al., 2015; Paria et al., 2016). Additionally, ginger has been found effective in alleviating symptoms such as dry mouth (xerostomia) in diabetic patients (Homeira et al., 2017).

In experimental models, ginger demonstrates protective effects on pancreatic β-cells. Diabetes induced by streptozotocin (STZ) or alloxan results in oxidative stress and pancreatic cell damage, with STZ impairing β-cell function and alloxan causing cytotoxicity leading to vascular damage and clinical signs of T1DM (Kondeti et al., 2011; Valter and Rosa, 2015). Ginger treatment mitigates these effects by normalizing glycemic levels, enhancing antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), and increasing glutathione reductase (GR) and glutathione (GSH) levels.

Environmental factors, such as exposure to inorganic arsenic (IA), have been linked to T2DM. Ginger's antioxidant properties may counteract the effects of IA, which disrupts glucose homeostasis and exacerbates diabetes-related complications (Felicia et al., 2020; Macario et al., 2021). These findings suggest that ginger not only aids in diabetes management but also offers protective effects against environmental factors contributing to the disease.

### 2.7. Cardioprotective Activity of Ginger

Ginger (*Zingiber officinale*) has demonstrated significant cardioprotective effects through multiple mechanisms. Studies indicate that it reduces levels of low-density lipoprotein (LDL) cholesterol and triglycerides, which are critical factors in the development of cardiovascular diseases. Ginger also prevents atherogenesis by inhibiting the formation of atheroma plaques in blood vessels. Furthermore, it improves endothelial function, thereby enhancing vascular elasticity and reducing the risk of hypertension and ischemic heart diseases (Azimi et al., 2016).

A systematic review of clinical trials further highlights ginger's role in reducing markers of oxidative stress and inflammation, both of which contribute to the progression of cardiovascular diseases (Wang et al., 2017). These findings suggest that ginger may serve as a natural adjunct in managing coronary artery diseases.

### 2.8. Antidepressant Properties of Ginger

Depression is primarily attributed to an imbalance of neurotransmitters such as serotonin, norepinephrine, and dopamine. Conventional antidepressants aim to restore this balance, especially by increasing serotonin levels. Natural compounds like honokiol and magnolol (HMM) from Magnolia officinalis and ginger essential oils (GEO) and polysaccharides (PGR) have been studied for their potential antidepressant effects.

In animal studies, combinations of these compounds demonstrated significant synergistic effects. A combination of 39 mg/kg of PGR and 15 mg/kg of HMM administered for two weeks significantly increased serotonin and noradrenaline levels in the prefrontal cortex, highlighting its potential for depression treatment (Tahir et al., 2015; Qiang et al., 2009). These findings suggest a promising natural alternative to conventional antidepressants.

Moreover, ginger extracts combined with Nigella sativa oil were found to mitigate anxiety and depression behaviors induced by mercury ($HgCl_2$) exposure in Wistar rats. This effect is likely attributed to 6-gingerol, a neuroprotective compound in ginger, and thymoquinone, the active ingredient in Nigella sativa, which is known for its antidepressant properties. Together, these compounds exhibit a synergistic effect in reducing depressive symptoms (Benkermiche et al., 2021; Yi et al., 2009).

Given the increasing prevalence of anxiety, depression, and related conditions, these findings underscore the potential of ginger and its combinations as both preventative measures and treatments for mood disorders.

### 2.9. Antispasmodic Activity of Ginger

Ginger (*Zingiber officinale*) is known for its antispasmodic properties, which make it effective in relieving muscle spasms, particularly in the gastrointestinal tract. The bioactive compounds in ginger, such as gingerol and shogaol, exert their effects by modulating smooth muscle contractions. These compounds are believed to inhibit calcium influx into smooth muscle cells, thereby reducing spasms and providing relief from conditions such as irritable bowel syndrome and colic (Ghayur & Gilani, 2005).

Furthermore, ginger's ability to alleviate gastrointestinal discomfort has been supported by its traditional use and clinical studies, making it a promising natural remedy for managing functional gastrointestinal disorders (Ali et al., 2008).

### 2.10. Antifungal Activity of Ginger

Ginger oil exhibits significant antimicrobial properties, including antifungal activity, due to its rich composition of oxygenated compounds. The fresh form of ginger contains a higher concentration of these compounds compared to its dried counterpart, which explains its enhanced antimicrobial effects (Preedy, 2016; Sasidharan and Menon, 2010).

The antifungal mechanism of essential oils, including ginger oil, often involves targeting ergosterol, the primary sterol in fungal cell membranes. Ergosterol plays a critical role in maintaining cell function and structural integrity. Natural and synthetic antifungal agents, such as azoles, disrupt sterol biosynthesis, reducing ergosterol levels and subsequently inhibiting fungal growth (Tian et al., 2012).

Essential oils are classified as Generally Recognized as Safe (GRAS) and exhibit a low risk of inducing resistance in pathogenic microorganisms. This characteristic makes them attractive alternatives to traditional antifungal agents. Furthermore, the antifungal properties of essential oils are attributed to their bioactive compounds, which have been widely studied for their efficacy against various fungi (Cardile et al., 2009; Kordali et al., 2005).

These findings highlight the potential of ginger oil and its bioactive constituents as natural antifungal agents, offering an effective and safer alternative to conventional treatments.

### 2.11. Analgesic Activity

Ginger (*Zingiber officinale*) has demonstrated considerable promise in alleviating pain associated with a wide range of conditions, including arthritis, irritable bowel syndrome, primary dysmenorrhea, postoperative recovery, and migraines. Data from both preclinical and clinical studies indicate ginger's efficacy as a natural analgesic, reducing chronic pain across various disorders. Several reviews have summarized findings on the pharmacological mechanisms, clinical efficacy, and potential side effects of ginger and its bioactive constituents (Rondanelli et al., 2020; Chrubasik et al., 2005).

Despite strong evidence for its broad-spectrum analgesic properties, the comprehensive understanding of ginger's mechanism of action remains limited. Current research shows scattered data on the analgesic effects of individual compounds, the specific types of pain they alleviate, and the molecular mechanisms involved. A systematic review of 11 in vitro and 16 in vivo studies investigating ginger extract or its components highlighted the need for a deeper understanding of these mechanisms. This knowledge could enhance therapeutic applications and provide more effective strategies for treating chronic pain by targeting key molecular pathways (Rondanelli et al., 2020; Srinivasan, 2017).

### 2.12. Antiviral Activity

Ginger (*Zingiber officinale*) has shown promising prophylactic and therapeutic antiviral effects across various studies. Fresh ginger has demonstrated antiviral activity against Human Respiratory Syncytial Virus (HRSV) by reducing plaque formation in respiratory mucosal cell lines. At high concentrations, it stimulates the secretion of interferon-beta (IFN-β), which inhibits viral attachment and internalization (Chang et al., 2013).

Additionally, ginger's lyophilized juice extract has been shown to inhibit Hepatitis C viral replication in Hep G2 cells by targeting viral RNA, indicating its potential in treating Hepatitis C infections (El-Wahab et al., 2009). Furthermore, aqueous extracts of ginger effectively combat Feline Calicivirus, a surrogate for Human Norovirus, highlighting its potential for addressing alimentary infections caused by foodborne pathogens (Aboubakar et al., 2016).

Allicin, a bioactive compound in ginger, exhibits anti-influenza cytokine activity, suggesting effectiveness against Influenza A (H1N1) (Sahoo et al., 2016). Moreover, ginger essential oil has shown activity against genital Herpes Simplex Virus type 2 (HSV-2) by interfering with the viral envelope before adsorption (Koch et al., 2008). It has also demonstrated virucidal effects on acyclovir-resistant HSV-1 strains, reducing plaque formation and offering an alternative for drug-resistant cases (Schnitzler et al., 2007).

### 2.13. Anti-allergic Activity

Ginger exhibits significant anti-allergic properties by inhibiting histamine release and reducing allergic reactions. The phenolic compounds, particularly 6-gingerol and 6-shogaol, play a vital role in modulating immune responses, thereby decreasing hypersensitivity reactions. In cellular models, these compounds suppress the production of pro-inflammatory cytokines and histamine release, effectively mitigating allergic responses (Chen et al., 2009).

### 2.14. Hepatoprotective Activity

Ginger demonstrates hepatoprotective effects by safeguarding the liver from toxins and oxidative damage. The bioactive compounds, such as gingerol and zingerone, enhance antioxidant defense mechanisms, reducing lipid peroxidation and promoting the detoxification of harmful substances. These effects are particularly effective against drug-induced and alcohol-induced hepatic damage (Gholampour et al., 2017).

### 2.15. Gastroprotective Activity

Ginger is widely recognized for its gastroprotective effects, alleviating conditions such as indigestion, ulcers, and irritable bowel syndrome (IBS). Its anti-inflammatory and antioxidant properties protect gastric mucosa from damage caused by stress, alcohol, or Helicobacter pylori infections. Moreover, ginger enhances gastrointestinal motility and reduces the severity of dyspeptic symptoms (Mahady et al., 2003).

### 2.16. Anti-emetic Activity

Ginger is highly effective in alleviating nausea and vomiting associated with pregnancy, chemotherapy, and motion sickness. Its anti-emetic effects are primarily attributed to the bioactive compounds 6-gingerol and shogaol, which influence gastric motility and act on serotonin receptors in the gastrointestinal tract and central nervous system (Ernst & Pittler, 2000). Clinical studies have consistently demonstrated the efficacy of ginger in reducing nausea during the first trimester of pregnancy and improving symptoms in chemotherapy patients (Borrelli et al., 2005).

### 2.17. Antimicrobial Activity

Ginger exhibits potent antimicrobial properties, inhibiting the growth of bacterial and fungal pathogens such as Helicobacter pylori and Candida albicans. The compounds 6-gingerol and 6-shogaol disrupt microbial cell membranes, hinder biofilm formation, and interfere with bacterial quorum sensing. This activity makes ginger a potential therapeutic agent for managing infections, particularly gastrointestinal and oral infections (Park et al., 2008).

### 2.18. Anti-platelet and Antithrombotic Activity

Ginger demonstrates anti-platelet and antithrombotic effects by inhibiting platelet aggregation and reducing thrombus formation. This activity is attributed to gingerols, which inhibit cyclooxygenase and thromboxane synthesis, thus reducing the risk of cardiovascular events such as stroke and myocardial infarction. Studies also show that ginger's bioactive compounds regulate platelet function without causing adverse bleeding events (Lumb, 1994).

### 2.19. Neuroprotective Activity

Ginger offers neuroprotective benefits by reducing oxidative stress and inflammation in the brain, making it a promising candidate for managing neurodegenerative disorders like Alzheimer's and Parkinson's diseases. The active compounds, including 6-shogaol, scavenge free radicals, inhibit amyloid-beta aggregation, and modulate pro-inflammatory pathways, thereby slowing disease progression and improving cognitive function (Ojewole, 2006).

### 2.20. Ginger in the management of osteoarthritis

Ginger (Zingiber officinale) has shown promising potential in managing osteoarthritis (OA), a degenerative joint condition characterized by chronic pain and inflammation. Its bioactive components, such as gingerols and shogaols, are known for their anti-inflammatory and analgesic properties. A meta-analysis by Bartels et al. (2015) reported that ginger modestly reduced pain and improved physical function in individuals with OA. The study also highlighted that the adverse events reported were mild and transient, supporting ginger's safety profile. Similarly, a systematic review by Terry et al. (2011) found that ginger significantly alleviated subjective pain in OA patients, emphasizing its role as a natural alternative for pain management.

Recent clinical trials have further substantiated ginger's therapeutic potential in OA. For instance, Baek et al. (2024) conducted a randomized, double-blind, placebo-controlled study evaluating the efficacy of steamed ginger extract (GGE03) in patients with mild knee OA. The results demonstrated a significant reduction in pain and improved joint function among participants receiving the extract, with no notable safety concerns. These findings collectively suggest that ginger may serve as an effective adjunct therapy for osteoarthritis. However, more large-scale, high-quality trials are necessary to establish optimal dosages and assess long-term outcomes.

In summary, the pharmacological activities of ginger (Zingiber officinale) highlight its immense therapeutic potential across diverse biological systems. Its bioactive constituents, such as 6-gingerol, 6-shogaol, and zingerone, demonstrate notable anti-inflammatory, antioxidant, anticancer, and antimicrobial effects, validated through a wide range of in vivo and in vitro studies. These findings not only reinforce ginger's traditional medicinal applications but also open new avenues for its integration into modern pharmacotherapy and functional foods.

## 3. CONCLUSION

Ginger (Zingiber officinale) stands out as a versatile medicinal plant with a broad spectrum of pharmacological activities. Its bioactive compounds, particularly gingerols, shogaols, and paradols, exhibit significant therapeutic potential in addressing various health conditions, including inflammation, oxidative stress, cancer, diabetes, and gastrointestinal disorders. The accumulated evidence underscores ginger’s role as a safe and effective natural remedy with minimal side effects. However, while preclinical and clinical studies highlight its promising benefits, further research is required to elucidate its mechanisms of action fully, optimize its dosage forms, and confirm its efficacy in large-scale human trials. This positions ginger as a valuable candidate for developing novel therapeutic agents in modern medicine.

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