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ZINGIBER OFFICINALE (GINGER): A REVIEW ON ITS PHYTOCHEMISTRY AND THERAPEUTIC PROPERTIES

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ABSTRACT

Ginger (*Zingiber officinale*) is a medicinal plant widely recognized for its phytochemical richness and therapeutic potential. This review consolidates evidence from peer-reviewed studies published between 2000 and 2026, focusing on its chemical constituents and pharmacological activities. Major bioactive compounds include gingerols, shogaols, paradols, and zingerone, which demonstrate antioxidant, anti-inflammatory, antimicrobial, antiemetic, anticancer, antidiabetic, cardioprotective, and neuroprotective effects. While preclinical studies provide strong support for these properties, the limited number of human clinical trials underscores the need for further research to validate its therapeutic applications.

KEYWORDS: *Zingiber officinale*, gingerols, shogaols, phytochemistry, therapeutic properties.

1. INTRODUCTION

Zingiber officinale (ginger) is a perennial herb of the family Zingiberaceae, cultivated widely in tropical and subtropical regions such as India, China, Nigeria, Indonesia, and the Philippines. The rhizome is the most utilized part, serving as a spice, food ingredient, and medicinal resource. For centuries, ginger has been integral to traditional healing systems including Ayurveda, Traditional Chinese Medicine (TCM), and Unani medicine. It has been prescribed for nausea, vomiting, colds, cough, rheumatism, indigestion, and pain. In recent decades, scientific research has expanded on these traditional uses, identifying numerous bioactive compounds responsible for its diverse pharmacological effects. This review aims to synthesize existing studies on the phytochemistry and therapeutic properties of *Zingiber officinale*, with emphasis on its major bioactive constituents and their mechanisms of action in human health.

1.1 Botanical and Taxonomic Description of *Zingiber officinale*

Zingiber officinale is a flowering plant with underground rhizomes that are thick, branched, and aromatic. The plant usually grows up to 1–1.5 meters in height and has narrow, lance-shaped leaves arranged alternately on a pseudostem. The flowers are pale yellow-green with purple markings.

Taxonomic Classification

- **Kingdom:** Plantae
- **Division:** Magnoliophyta
- **Class:** Liliopsida
- **Order:** Zingiberales
- **Family:** Zingiberaceae
- **Genus:** *Zingiber*
- **Species:** *Zingiber officinale* Roscoe

The rhizome represents the medicinally valuable portion of the plant and contains the majority of its phytochemical constituents.

2. METHODOLOGY

A narrative review design was employed to synthesize existing literature on the phytochemistry and therapeutic properties of *Zingiber officinale*. Relevant articles were retrieved from PubMed, ScienceDirect, Google Scholar, and Research Gate using keywords such as "*Zingiber officinale*", "ginger phytochemistry", "shogaol", and "therapeutic properties".

The inclusion criteria were: (1) peer-reviewed articles published between 2000 and 2026, (2) studies written in English, and (3) research addressing the phytochemical composition or therapeutic effects of ginger. Exclusion criteria included non-English publications, anecdotal reports, and duplicate studies. Both *in vitro* and *in vivo* studies were considered to provide a comprehensive overview of ginger's pharmacological potential.

3. Phytochemistry of *Zingiber officinale*

Ginger contains a wide variety of phytochemicals responsible for its aroma, flavor, and medicinal activity. The main groups of compounds include phenolic compounds, volatile oils, terpenoids, flavonoids, and organic acids.

3.1 Major Bioactive Compounds

The primary phytochemical classes identified in *Z. officinale*, along with their specific bioactive constituents and principal pharmacological properties, are summarized in Table 1.

Table 1: Phytochemical composition and biological activities of *Zingiber officinale*.

Compound Group	Major Constituents	Main Biological Activity
Phenolic compounds	6-gingerol, 8-gingerol, 10-gingerol	Antioxidant, anti-inflammatory, anticancer
Dehydration products	6-shogaol, 8-shogaol, 10-shogaol	Antioxidant, neuroprotective, antiemetic
Ketone derivatives	Zingerone, paradol	Antimicrobial, anti-inflammatory
Volatile oils	Zingiberene, beta-bisabolene, cineole, citral	Aromatic, antimicrobial
Flavonoids & polyphenols	Quercetin, catechin	Antioxidant

3.2 Gingerols

Gingerols are the principal pungent active compounds found in fresh ginger rhizomes. Among them, 6-gingerol is the most abundant and pharmacologically active. These compounds are responsible for the characteristically spicy flavor of fresh ginger and serve as primary contributors to its antioxidant and anti-inflammatory properties.

Studies have shown that gingerols inhibit the biosynthesis of pro-inflammatory mediators that cause swelling and pain, such as prostaglandins, leukotrienes, and cytokines (Dugasani et al., 2010). They also mitigate oxidative stress by scavenging free radicals and upregulating the activity of endogenous antioxidant enzymes.

3.3 Shogaols

Shogaols are formed via the dehydration of gingerols during thermal processing or long-term drying. Consequently, dried ginger possesses a higher concentration of shogaols compared to fresh ginger. In several pharmacological assays, 6-shogaol has been found to be more potent than its precursor, 6-gingerol (Semwal et al., 2015). Shogaols exhibit pronounced antioxidant, anticancer, anti-inflammatory, and neuroprotective effects. They are particularly effective in downregulating inflammatory pathways and preventing neuronal damage induced by oxidative stress.

3.4 Volatile Oils

The characteristic aroma and fragrance of ginger are attributed to its volatile essential oil fraction, which constitutes approximately 1% to 3% of the rhizome. The major volatile constituents include sesquiterpenes such as zingiberene and beta-sesquiphellandrene, alongside monoterpenes like bisabolene, cineole, and citral (Singh et al., 2008). These volatile compounds contribute significantly to the antimicrobial and carminative properties of ginger. Essential oils extracted from the rhizome have demonstrated robust inhibitory activity against several bacterial and fungal strains.

4. Therapeutic Properties Of Ginger

4.1 Antioxidant Activity

Ginger possesses strong antioxidant activity due to its high content of gingerols, shogaols, and other phenolic compounds (Ali et al., 2008). These molecules neutralize reactive oxygen species (ROS) and reduce oxidative stress, which is fundamentally linked to aging and chronic pathogenesis. Several studies indicate that ginger extract increases the expression of antioxidant enzymes, including superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx), thereby protecting cellular structures from oxidative degradation (Mashhadi et al., 2013).

4.2 Anti-inflammatory Activity

One of the most thoroughly documented therapeutic features of ginger is its anti-inflammatory action. Ginger inhibits key enzymatic pathways involved in inflammation, specifically cyclooxygenase (COX) and lipoxygenase (LOX), while suppressing pro-inflammatory cytokines like tumor necrosis factor-alpha (TNF-alpha) and interleukins (ILs) (Ali et al., 2008; Dugasani et al., 2010). Accordingly, ginger has been clinically evaluated for chronic inflammatory joint disorders, such as osteoarthritis and rheumatoid arthritis, where trials indicate supplementation can reduce joint pain, stiffness, and swelling.

4.3 Antiemetic and Gastroprotective Effects

Ginger is widely implemented as a natural intervention for nausea and emesis. Clinical applications have demonstrated efficacy in managing:

- Motion sickness
- Morning sickness during pregnancy
- Postoperative nausea and vomiting (PONV)
- Chemotherapy-induced nausea and vomiting (CINV)

The antiemetic mechanism of action is mediated through its modulation of gastric motility and antagonism of serotonin (5-HT_3) receptors in the gastrointestinal tract (Bode & Dong, 2011). Furthermore, ginger stimulates digestive enzymes, mitigates dyspepsia, and exhibits gastroprotective effects by maintaining mucosal integrity against ulceration.

4.4 Antimicrobial Activity

Extracts and essential oils of ginger exhibit a broad spectrum of antimicrobial activity against pathogenic microorganisms, including:

- *Escherichia coli*
- *Staphylococcus aureus*
- *Salmonella* species
- *Candida albicans*

This antimicrobial effect is primarily driven by gingerols, shogaols, and specific volatile monoterpenes, which induce structural damage to microbial cell membranes and interrupt metabolic replication (Singh et al., 2008).

4.5 Antidiabetic Activity

Emerging evidence suggests that ginger plays a beneficial role in the metabolic regulation of diabetes mellitus. It enhances insulin sensitivity, reduces fasting blood glucose, and improves glycated hemoglobin (HbA1c) profiles (Butt & Sultan, 2011). This antidiabetic efficacy is attributed to the facilitation of peripheral glucose uptake, the inhibition of carbohydrate-metabolizing enzymes (alpha-glucosidase and alpha-amylase), and the protection of pancreatic beta-cells from oxidative degradation.

4.6 Cardioprotective Effects

Ginger supports cardiovascular health through mechanisms that lower blood pressure, reduce serum cholesterol levels, and inhibit platelet aggregation (Rahmani et al., 2014). Its antioxidant actions prevent low-density lipoprotein (LDL) oxidation, a critical step in atherogenesis. Studies have demonstrated that consistent ginger supplementation significantly decreases total cholesterol, LDL, and triglycerides, while simultaneously increasing high-density lipoprotein (HDL) levels.

4.7 Anticancer Activity

Bioactive compounds in ginger, particularly gingerols and shogaols, display notable chemo preventive and chemotherapeutic properties *in vitro* and *in vivo*. These compounds restrict the proliferation of malignant cells, induce intrinsic apoptosis, and suppress angiogenesis and tumor growth (Shukla & Singh, 2007). Literature highlights the potential therapeutic efficacy of ginger against colon, breast, pancreatic, hepatic, and prostate malignancies, modulated through the inhibition of chronic inflammatory pathways and cellular survival signals.

4.8 Neuroprotective Effects

Ginger exhibits promising neuroprotective properties. The antioxidant components clear neurotoxic free radicals and suppress neuroinflammation, which are key drivers of neurodegenerative diseases such as Alzheimer's disease and Parkinson's disease (Extract; Semwal et al., 2015). Experimental studies indicate that ginger extracts can improve memory retention, spatial learning, and overall cognitive function by preventing neuronal cell death and optimizing neurotransmitter activity.

5. DISCUSSION AND LIMITATIONS

The reviewed scientific literature indicates that *Zingiber officinale* provides substantial health-promoting benefits attributable to its diverse secondary metabolites. Phenolic compounds, notably gingerols and shogaols, are the primary drivers of these medicinal outcomes.

However, several limitations must be addressed in future research. The majority of the pharmacological data generated thus far stems from *in vitro* laboratory models or *in vivo* animal studies (Chandrasekaran et al., 2016). Robust human clinical trials remain scarce, particularly regarding long-term toxicological safety, bioavailability, and definitive efficacy against chronic pathologies such as advanced malignancies, diabetes, and neurodegenerative disorders.

An additional challenge is the lack of standardized protocols for preparing ginger derivatives. The concentrations of bioactive molecules vary significantly based on geographic origin, agronomic practices, processing methodologies, and whether fresh or dried matrices are utilized (Semwal et al., 2015). This biochemical variability limits the reproducibility and comparability of data across different clinical and experimental models. Future investigations must focus on utilizing standardized ginger extracts, executing larger randomized controlled trials (RCTs), and elucidating the definitive molecular pathways involved.

6. CONCLUSION

Zingiber officinale represents a highly versatile medicinal plant with extensive therapeutic potential. Its clinical benefits stem from an array of natural bioactive compounds, including gingerols, shogaols, zingerone, and essential volatile oils.

These constituents act synergistically as antioxidant, anti-inflammatory, antimicrobial, antiemetic, antidiabetic, cardioprotective, neuroprotective, and chemo-preventive agents. The collective empirical data strongly validate the traditional ethnomedical applications of ginger. Nonetheless, rigorous human trials are essential to establish standardized dosing regimens, confirm long-term safety profiles, and translate these preclinical insights into validated clinical therapeutics.

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