DOI 10.26724/2079-8334-2025-4-94-229-238
UDC 615.322:582.548.27:615.276

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PHARMACOLOGICAL PROPERTIES AND THERAPEUTIC POTENTIAL OF ZINGIBER OFFICINALE ROSCOE

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Ginger rhizome is included in the British Herbal Pharmacopoeia, the Pharmacopoeias of China, Japan, Egypt, Austria and Switzerland. The aim of the review is to summarize the literature on the phytochemistry of the main action molecular mechanisms and pharmacological properties of Zingiber officinale Roscoe, as well as the results of studies of its use in the last five years. Numerous studies have shown that ginger contains nutritional components essential for health. Zingiber officinale Roscoe contains a variety of nutrients, such as carbohydrates, amino acids, proteins, vitamins, minerals, fatty acids, lipids, a large number of phytochemicals, especially essential oils and phenolic compounds and other biologically active compounds. The biological activity of ginger and its chemical compounds is promising for the treatment and prevention of diabetes, obesity, nausea, vomiting, and inflammation. Research results have demonstrated potent antioxidant, as well as anti–inflammatory and antiemetic properties, The biological activity of ginger and its chemical compounds is promising for the treatment and prevention of diabetes, obesity, nausea, vomiting, and inflammation. Research results have demonstrated potent antioxidant, as well as anti–inflammatory and antiemetic properties, pregnancy–associated nausea and vomiting of ginger compounds. Findings from studies suggest that Zingiber officinale Roscoe supplements are beneficial for obesity and lipid metabolism disorders, but additional clinical studies are needed to support their efficacy and safety. It has been established that in patients with diabetes mellitus, the supplementation of Zingiber officinale had a positive effect on glycometabolic parameters, some markers of inflammation, oxidative stress, and the progression of kidney damage in diabetic kidney disease.

Key words: phytotherapy, Zingiber officinale Roscoe, biological activity, pharmacological effects, antiemetic properties, antioxidant activity, antimicrobial activity.

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ОГЛЯД ФАРМАКОЛОГІЧНИХ ВЛАСТИВОСТЕЙ І ТЕРАПЕВТИЧНОГО ПОТЕНЦІАЛУ ZINGIBER OFFICINALE ROSCOE

Кореневища імбиру входить до Британської трав'яної фармакопеї, фармакопеї Китаю, Японії, Єгипту, Австрії, Швейцарії. Метою огляду є узагальнення літературних джерел щодо фітохімії основних молекулярних механізмів дії та фармакологічних властивостей Zingiber officinale Roscoe, а також результатів досліджень його використання за останні п’ять років. Численні дослідження показали, що імбир містить поживні компоненти, необхідні для здоров'я, Zingiber officinale Roscoe містить безліч поживних речовин, таких як вуглеводи, амінокислоти, білки, вітаміни, мінерали, жирні кислоти, ліпіди, велику кількість фітохімічних речовин, особливо ефірних олій і фенольних сполук та інші біологічно активні речовини. Біологічна активність імбиру та його хімічних сполук є перспективною для лікування та профілактики цукрового діабету, ожиріння, нудоти, блювання, а також запалення. Результати досліджень продемонстрували потужні антиоксидантні, а також протизапальні та протиблювотні властивості сполук імбиру. Результати досліджень свідчать про позитивний вплив добавок Zingiber officinale Roscoe при ожирінні, порушеннях ліпідного обміну, цукровому діабеті (глікемічних параметрів, гемоглобін A1C (HbA1c) та інсулінорезистентності,) але потрібні подальші клінічні дослідження для підтвердження їх ефективності та безпеки. Встановлено, що у пацієнтів з цукровим діабетом додадавання Zingiber officinale приводило до позитивного вплиу на глікометаболічні параметри, деякі маркери запалення, оксидативного стресу та прогресування ураження нирок при діабетичній хворобі нирок.

Ключові слова: фітотерапія, кореневища імбиру**,** Zingiber officinale Roscoe, біологічна активність, фармакологічні ефекти, протиблювотні властивості, антиоксидантна активність, антимікробна дія.

The work is a fragment of the research project “To determine the features of immunocytokine imbalance in comorbid patients with hypertension and type 2 diabetes and cardiovascular and renal complications”, state registration No. 0123U101711.

Ginger has been cultivated for thousands of years as a spice, flavoring, and natural food additive in China, India, Greece, and other countries. The plant's distinctive yellow, pungent–smelling rhizome provides the spice's value and is a source of resin and essential oil. Ginger rhizomes have been used to treat a variety of conditions, including gastrointestinal disorders, fever, infectious diseases, sore throats, cramps, arthritis, muscle aches, and more [13]. In traditional Chinese medicine, Zingiber officinale Roscoe is used to relieve cold symptoms, stop vomiting, improve phlegm, and relieve coughs, as well as to treat fish poisoning, stomach disorders, and coughs with phlegm associated with colds [32]. Ginger is primarily used to prevent motion sickness symptoms [12].

Ginger (Zingiber officinale Roscoe) is a well–known food, spice, additive and flavouring. Traditionally, ginger and its products (ginger biscuits, ginger coffee, ginger drink, ginger oil, ginger spice, ginger syrup and ginger wine) are used in the food, brewing and related industries [41]. It is used in traditional medicine due to its beneficial properties such as pungency, aroma, nutrients and pharmacological activity [22].

Ginger rhizome is included in the British Herbal Pharmacopoeia, the Pharmacopoeias of China, Japan, Egypt, Austria and Switzerland.

The purpose of the study was to summarize the literature on the phytochemistry of the main action molecular mechanisms and pharmacological properties of Zingiber officinale Roscoe, as well as the results of studies on its use.

In this study, we conducted a systematic analysis of data found in PubMed and ResearchGate databases, from 2021 to 2025.

Database 1 – PubMed – Search query: ("Zingiber officinale" AND/OR "Ginger essential oil" AND/OR "Chemical composition") AND ("Biological activity" OR "Pharmacological properties") AND/OR ("Antiemetic properties" OR "Vomiting") AND/OR ("Antioxidant properties" OR "Antioxidant") AND/OR ("Antimicrobial activity" OR "Antibiotic resistance" OR "Antifungal-drug resistance") AND/OR ("Obesity" OR "Weight loss") AND/OR (" Diabetes" OR "Renoprotective effect").

Database 2 – ResearchGate – Search query: ("Zingiber officinale" AND/OR "Ginger essential oil" AND/OR "Chemical composition") AND ("Biological activity" OR "Pharmacological properties") AND/OR ("Antiemetic properties" OR "Vomiting") AND/OR ("Antioxidant properties" OR "Antioxidant") AND/OR ("Antimicrobial activity" OR "Antibiotic resistance" OR "Antifungal-drug resistance") AND/OR ("Obesity" OR "Weight loss") AND/OR (" Diabetes" OR "Renoprotective effect").

The last literature search was performed on October 31, 2025. Studies published between 2021 and 2025 were involved in the review, while articles published prior to 2021 were excepted. This review included systematic reviews, meta-analyses, experimental and clinical studies. A total of 50 articles were selected which were published from January 1, 2021 to October 31, 2025.

The works included in the analysis are presented in Table 1.

Table 1

Simplified PRISMA Flow

Stage	Description	Number of Records/Studies
1. Identified	Total number of records identified through database searching and other sources	557
2. Duplicates Removed	Number of records removed before screening (e.g., duplicates)	347
3. Screened (Title/Abstract)	Number of records screened after duplicates were removed	210
4. Assessed for Eligibility (Full-text)	Number of full-text articles assessed for eligibility against the inclusion/exclusion criteria	108
5. Included in Review	Total number of primary studies finally included in the systematic review	50

Ginger contains a variety of nutrients, such as carbohydrates (about 18 %), amino acids and proteins (2 %), vitamins and minerals, fatty acids and lipids (1 %), and a large number of phytochemicals, especially essential oils and phenolic compounds [16, 19]. The rhizomes contain 1.5–3 % essential oil, the main component of which is terpenoids [50]. More than 100 chemical compounds have been isolated from ginger rhizomes, including gingerols, essential oils, diarylheptanoids, etc. [24].

Ginger essential oils give Zingiber officinale Roscoe a unique aroma. The pungent taste of the rhizomes is due to the resinous part (phenolic ketones), known as "gingerol", which is a mixture of various gingerols (gingerols) – 5–8 %. 28 compounds have been identified in the essential oil, most of which are sesquiterpenes (53.57 %) and monoterpenes (21.87 %) [37]. The main components of ginger essential oils are considered to be β–bisabolene, α–curcumene, zingiberene, α–farnesene and β–sesquiphellandrene,

Zingiber officinale Roscoe is rich in various chemical components, including phenolic compounds, terpenes, polysaccharides, lipids, organic acids (oxalic, tartaric, lactic, citric, succinic, etc.), and crude fiber [12, 32]. Zingiber officinale contains a number of antioxidants such as beta–carotene, ascorbic acid, terpenoids, alkaloids, and polyphenols such as flavonoids, flavone glycosides, rutin, etc. [47]. The phenolic compounds in ginger are mainly gingerols, shogaols and paradols [8]. In fresh ginger, gingerols are the main polyphenols, such as 6–gingerol, 8–gingerol and 10–gingerol [49]. During heat treatment or long–term storage, gingerols are converted to the corresponding shogaols (which give the smell and burning taste to ginger powder). After hydrogenation, shogaols can be converted to paradols [41]. Other phenolic compounds in ginger are quercetin, zingerone, gingerenone–A and 6–dehydrogingerdione [41].

Ginger also contains amino acids (glutamate, aspartic acid, serine, glycine, threonine, alanine, cystine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, lysine, histidine, arginine, proline, tryptophan); vitamins (C, B_3, B_4, B_6, etc.) and other biologically active compounds [38]. It has been established that ginger rhizome contains useful trace elements, namely: calcium, potassium, phosphorus and magnesium in higher concentrations, as well as significant amounts of copper, cobalt, iron, nickel, manganese, sodium and zinc, etc. [41].

The health benefits of ginger are mainly attributed to its phenolic compounds such as gingerols and shogaols. Cumulative studies have shown that ginger has many biological properties, including antioxidant, anti–inflammatory, antimicrobial, antitumor, neuroprotective, cardioprotective. In addition, ginger is used to treat gastrointestinal infections and to relieve headache, nausea, vomiting, dizziness, rheumatic diseases, etc. Thus, 6–gingerol is known for its potent anti–inflammatory, antioxidant, and anticancer properties; it can be found in high concentrations, especially in fresh ginger [49].

Matin M. et al. [25] conducted a systematic review that included studies using ginger. They found that among 89 trials, the treatment effect was 47.2 %, and the most common types of intervention were dietary supplements (40.4 %) and medications (27 %). They showed that the studies included various health outcomes, including antiemetic activity, analgesic function, effects on health–related quality of life, blood pressure fluctuations, energy expenditure, and reduction of xerostomia. The authors concluded that the study analysis provided a comprehensive overview of clinical trials of ginger, focusing on its wide range of potential health benefits.The biological activities of Zingiber officinale rhizomes are shown in Fig. 1 [17].

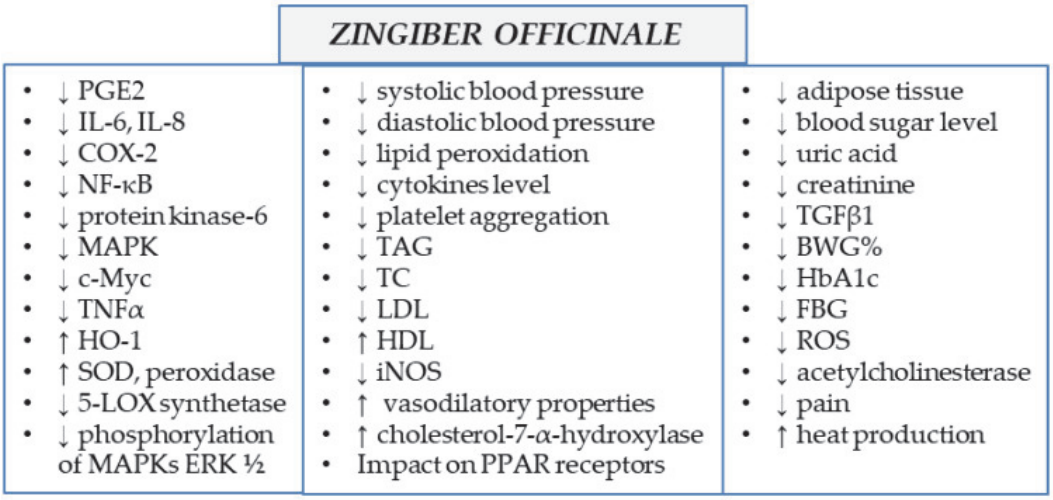

Fig. 1. Molecular mechanism of action of Zingiber officinale rhizomes. Notes: ↓ – decrease; ↑ – increase [17].

The effectiveness of ginger rhizome for the prevention of nausea, dizziness, and vomiting as symptoms of motion sickness (kinetosis), as well as for the relief of nausea and vomiting caused by surgery [12].

In a clinical trial of 92 patients undergoing abdominal hysterectomy who were randomized to receive either oral ginger (1 g) and dexmedetomidine injection (25 mg) before and after anesthesia, ginger was found to be more effective than dexmedetomidine [11]. This study also found that ginger treatment significantly reduced vomiting rates 2 hours after surgery compared to dexmedetomidine; however, by 4 hours, both treatments had completely stopped vomiting. In addition, ginger reduced the amount or frequency of nausea more than dexmedetomidine

In another study, 88 patients aged 30 to 70 years (both sexes) after laparoscopy were randomly assigned to receive different treatments: ginger (4 capsules), haloperidol, metoclopramide, and dexmedetomidine [5]. No significant difference was found between the treatments in terms of the effect on nausea. The authors concluded that ginger and the comparators can be used to treat vomiting and nausea, but without serious side effects.

In a triple–blind clinical trial involving 148 patients undergoing eye surgery, patients were randomized to receive ginger, ondansetron (the reference) or placebo [4]. The efficacy of ginger in reducing the frequency and severity of nausea and vomiting in patients was studied. Oral administration of ginger capsules (1000 mg) and ondansetron was shown to significantly reduce vomiting compared with placebo, but no significant difference was observed in the amount of vomiting and the severity of nausea. The authors concluded that ginger was more effective, safer and less expensive than ondansetron, and therefore could be used as an alternative therapy for nausea and vomiting.

In a clinical trial [15] of women with hyperemesis gravidarum, each woman was given capsules containing 250 mg of ginger or lactose 4 times daily for the first 4 days of the treatment period. After a 2–day washout period, the alternative treatment was given during the second 4–day period. The severity and relief of symptoms before and after each period were assessed using two scoring systems. By subjective assessment, 19 women (70.4 %) preferred the period when they were later found to have taken ginger (P=0.003). By more objective assessment, scores showed significantly greater relief of symptoms after ginger treatment compared with placebo (P=0.035). No adverse effects were observed.

Viljoen E. et al. [18] conducted a systematic review and meta–analysis of 12 randomized clinical trials (1278 pregnant women) on the use of ginger in pregnancy–associated nausea and vomiting. It was found that ginger was more effective than placebo in reducing the severity of nausea and vomiting. Thus, ginger significantly alleviated nausea symptoms compared with placebo (MD 1.20, 95 % CI 0.56–1.84, p=0.0002, I^2=0 %). At the same time, ginger did not significantly affect vomiting episodes and did not pose a risk for side effects or adverse events during pregnancy.

A meta–analysis of 30 studies or 1174 patients found that ginger was effective in reducing symptoms of nausea and vomiting in pregnant women and nausea compared to a control group, but no significant effect was found on vomiting [31]. In addition, ginger consumption was more effective than vitamin B6 in alleviating nausea and vomiting during pregnancy.

Although ginger has been shown to be effective in most studies in preventing nausea, some clinical studies have been conflicting. A clinical trial [14] examined the effects of ginger on both acute and delayed chemotherapy–induced nausea and vomiting in breast cancer patients. Assessments were made within the first 6 hours, between 6 and 24 hours, and on days 2, 3, and 4 after chemotherapy. It was found that adding ginger (1.5 g/day) to standard antiemetic therapy (granisetron plus dexamethasone) in breast cancer patients was effective in reducing the prevalence of nausea 6 to 24 hours after chemotherapy. Despite this effect, no other significant additional benefits of ginger (1.5 g/day) were found on the prevalence or severity of nausea, vomiting, and retching at any of the time points evaluated.

Choi J. et al. [11] conducted a meta–analysis of 23 randomized clinical trials of ginger supplementation compared with placebo or antiemetics on acute and delayed chemotherapy–induced nausea. They found that the incidence of acute nausea (p=0.53), delayed nausea (p=0.31), acute vomiting (p=0.09), and delayed vomiting (p=0.89) were not significantly different between the ginger supplementation group and the control group. The group that took no more than 1 g of ginger per day for more than four days had significantly less acute vomiting than the control group (OR 0.30; 95 % CI 0.12 to 0.79; p=0.02; I2=36 %). Ginger supplementation has been shown to reduce the incidence of acute chemotherapy–induced vomiting. However, the effect of ginger supplementation on the incidence of chemotherapy–induced nausea and delayed vomiting was not confirmed. The authors concluded that further research is needed in this area.

A clinical trial [27] involving patients with functional dyspepsia evaluated the effects of ginger on gastric motility and emptying, abdominal symptoms, and hormones that influence motility in dyspepsia. After an 8–hour fast, patients consumed three capsules containing ginger (total 1.2 g) or placebo, and 1 hour later, 500 ml of low–nutrient soup. Gastric emptying was found to be faster after ginger than after placebo [median (range) half–empty time 12.3 (8.5–17.0) min after ginger and 16.1 (8.3–22.6) min after placebo, P≤0.05]. There was a trend toward increased antral contractions (P=0.06), but gastric fundus dimensions and gastrointestinal symptoms did not differ, as did plasma concentrations of glucagon–like peptide–1 (GLP–1), motilin, and ghrelin.

In a study [4] involving 51 patients with functional dyspepsia, who were given Swanson ginger at a dose of 540 mg/day before lunch and dinner for four weeks, significant changes were observed in most dyspeptic symptoms after treatment, namely: feeling of heaviness in the epigastrium after eating (p=0.033, 95 % CI = 0.01–0.26), early satiety (p=0.001, 95 % CI = 0.10–0.37), epigastric pain (p=0.000, 95 % CI = 0.16–0.42), burning in the epigastrium (p=0.003, 95 % CI = 0.10–0.45) and heartburn (p=0.209, 95 % CI=–0.04–0.20). The data obtained allowed the authors to conclude that ginger can be considered as a promising alternative adjunctive remedy for the treatment of functional dyspepsia.

Therefore, ginger and its components can be considered as an alternative adjunct in the treatment of functional dyspepsia, but more extensive clinical studies are needed.

A double–blind, randomized trial [44] involving 80 Danish cadets tested the effect of powdered ginger root (Zingiber officinale) on seasickness. After a single dose of 1 g of ginger powder or placebo, symptoms of seasickness were assessed over the next 4 hours. Ginger root reduced the tendency to vomit and cold sweats, and symptoms of nausea and dizziness significantly better than placebo, but the difference was not statistically significant (p > 0.05).

Another study [46] investigated the mechanism of intestinal peristalsis inhibition by Zingiber officinale Roscoe using integrated metabolomics, serum pharmacochemistry, and network pharmacology. Metabolomics was used to identify differential metabolites, metabolic pathways, and pharmacodynamics, and then the data were combined with network pharmacology to explore potential targets of ginger that inhibit intestinal peristalsis in the treatment of diarrhea.The identified targets were further validated by molecular docking and molecular dynamics modeling. It was found that 25 active components of ginger (six major components), 35 potential key targets (three major targets), 40 differential metabolites (four key metabolites), and four major metabolic pathways were involved in the process by which ginger inhibits intestinal peristalsis during the treatment of diarrhea. Through the study, the complex mechanism of action and pharmacodynamic properties of ginger in inhibiting intestinal peristalsis were identified.

The gut microbiome is involved in many metabolic processes in the human body and is mainly responsible for regulating the metabolism of the host. It is known that changes in the function and composition of the gut microbiota affect the pathogenesis of metabolic diseases by inducing epigenetic changes, such as DNA methylation, histone modifications, and regulation by non–coding RNAs. These induced epigenetic modifications can also be regulated by metabolites produced by the gut microbiota, including short–chain fatty acids, folate, biotin, and trimethylamine–N–oxide [39].

In an experimental study by Wang J. et al. [45], the effect of ginger on obesity prevention was studied, namely the relationship between intestinal microbiota and metabolic adaptations resulting from ginger consumption in mice. Significant reductions in body weight, hepatic steatosis and mild inflammation, as well as improvements in insulin resistance were found in mice fed a high–fat diet (HFD) supplemented with ginger. Ginger supplementation was found to modulate the composition of the gut microbiota and increase the abundance of species belonging to the genus Bifidobacterium and SCFA–producing bacteria (Alloprevotella and Allobaculum), as well as increase the concentration of SCFA in feces. The authors concluded that the modulation of the gut microbiota by ginger consumption has a therapeutic effect on obesity in mice.

Modern pharmacological studies have shown that Zingiber officinale Roscoe can improve digestion, improve blood circulation, lower lipid levels and blood sugar levels, and have anti–inflammatory, antitumor, antimicrobial, and antioxidant effects [3, 7, 10, 48].

Ginger exhibits antioxidant properties, which are associated with compounds such as shogaol, gingerol, zingerone and paradol, thereby reducing the production of reactive oxygen species (ROS). It has been demonstrated that 6–shogaol and especially 6–gingerol, present in Zingiber officinale, have shown significant antioxidant activity in vitro [29]. Thus, in a study conducted by Ahmed S. et al. [3], fourteen 6–gingerol derivatives, including eight novel compounds, were synthesized and their antiplatelet, COX–1 inhibitory and antioxidant activities were studied to select candidates for pilot and preclinical studies. It was found that 6–gingerol can effectively inhibit xanthine oxidase, the enzyme responsible for catalyzing the oxidation of hypoxanthine to xanthine and xanthine to uric acid, preventing the formation of reactive oxygen species (ROS) at the final stage of purine metabolic breakdown. When studying pharmacodynamic and pharmacokinetic parameters, compounds were identified for further study that exhibited the best protective properties for the cardiovascular system, and one of the compounds was proposed as a potential antioxidant specific for the CNS.

In an experimental study [33], the protective properties of 6–gingerol fraction of Zingiber officinale (6–GRF) against chlorpyrifos–induced oxidative damage and inflammation in the brain and reproductive organs of rats were investigated. The study showed that 6–GRF protected against chlorpyrifos–induced increases in oxidative stress and levels of malondialdehyde, inflammatory mediators (myeloperoxidase), nitric oxide (NO), tumor necrosis factor–α (TNF–α) and apoptotic (caspase–3) markers. It was also found that 6–GRF increased the activities of the antioxidant enzymes catalase, superoxide dismutase, glutathione peroxidase and glutathione–S–transferase, as well as glutathione levels in the brain, ovaries and uterus of rats exposed to chlorpyrifos ($p<0.05$). Therefore, the protective effects of 6–GRF against chlorpyrifos–induced toxicity in the brain and reproductive organs of rats may be due to its potent antioxidant, anti–inflammatory, and anti–apoptotic properties.

Ginger has been shown to induce the replenishment of antioxidant enzymes such as superoxide dismutase (SOD) and catalase (CAT), increase glutathione levels, prevent lipid peroxidation, inhibit NO production, and neutralize hydroxyl radicals [5]. 6–gingerol also upregulates Beclin–1 expression, promoting autophagy in human endothelial cells, and inhibits PI3K/AKT/mTOR signaling without altering the cell cycle [33].

Rjabi S. et al. [36] conducted a meta–analysis that examined the dose–response effects of ginger (Zingiber officinale Roscoe, Zingiberaceae) supplementation on changes in inflammatory/oxidative status.

The study included 29 randomized controlled trials. Ginger supplementation was found to improve all biomarkers of inflammation/antioxidant activity, namely: C–reactive protein (CRP) (SRD=–0.86 mg/L; 95 % CI=–1.10, –0.62), tumor necrosis factor–α (SRD=–1.90 pg/mL; 95 % CI=–2.61, –1.18), interleukin–6 (SRD=–1.15 pg/mL; 95 % CI=–1.90, –0.41), total antioxidant capacity (SRD=0.22 mmol/L; 95 % CI=0.06, 0.38), malondialdehyde (SRD=–0.76 μmol/L; 95 % CI=–1.19, –0.33), and superoxide dismutase (SRD=48.12 U/L; 95 % CI=30.57, 65.58). The authors concluded that the effect of ginger on interleukin–6 was related to dosage and duration of intervention in a nonlinear manner. Ginger supplementation may improve inflammatory and antioxidant biomarkers, especially in people with comorbidities.

Another study [29] investigated the health benefits of antioxidant bioactive compounds in the leaves of Zingiber officinale. Using network pharmacological analysis combined with experimental validation, the authors investigated the antioxidant effects of ginger leaves and predicted targets for antioxidant activity. Nine major bioactive compounds in ginger leaves were identified using the internal standard method, and antioxidant activity was assessed using DPPH and ABTS free radical scavenging methods. Molecular docking data revealed that astragalin, a compound isolated from ginger leaves, had the highest connectivity in the compound–target network and was involved in inflammation–related biosynthesis, directly affecting cytokine gene expression and PTGS2 inhibition markers.

In addition, ginger enhances the expression of specific antioxidant elements such as glutathione, heme oxygenase–1, and quinone–1 through the activation of Nrf2. Ginger has been shown to inhibit the expression of the apoptosis protein Bax and prevent the expression of H2O2, malondialdehyde (MDA), and myeloperoxidase (MPO), and activate phosphatidylinositol–3–kinase (PI3K) and protein kinase B (Akt) of B cells, thereby providing a protective effect against cell damage caused by oxidative stress and inflammation [31].

The study investigated the effect of ginger resin (rich in gingerols and shogaols) on ionizing radiation–induced changes in human mesenchymal stem cells. It was found that ginger resin can significantly reduce ionizing radiation–induced cytotoxicity, generation of reactive oxygen species, and DNA strand breaks. The authors also studied the mechanism of scavenging reactive oxygen species by ginger resin. It was found that ginger resin can induce Nrf2 translocation to the cell nucleus and activate the expression of cytoprotective genes encoding heme oxygenase–1 (HO–1) and NAD(P)H:quinone oxidoreductase–1 (NQO–1). Therefore, ginger resin may play a role as an effective antioxidant and radioprotective agent [28].

Antimicrobial activity.

Compounds derived from ginger are known to exhibit potent antimicrobial activity against Gram–positive and Gram–negative bacteria, including even MDR strains [30]. In addition to its direct bacterial growth inhibitory properties, ginger has also been shown to attenuate various bacterial virulence factors and interfere with bacterial communication through quorum sensing and biofilm formation [26].

In a investigation [20], it was found that ginger essential oil inhibited the growth of 15 bacterial strains, 3 yeasts and 4 mycelial fungi. The most susceptible strains were S. aureus, S. epidemidis, E. faecalis, C. tropicalis and T. mentagrophytes. The antibacterial activity of Zingiber officinale Roscoe essential oil showed significant differences in inhibition of Gram–positive and Gram–negative bacteria ($p<0.0001$). The most susceptible were Gram–positive strains [30]. In microbial growth curves, the essential oil showed a bactericidal effect on S. aureus from the first hour of exposure to the strains, removing 99.9 % of the CFU at concentrations of 0.5 and 0.75 mg/ml, respectively [30]. Sensitivity of gram–negative strains, mainly P. aeruginosa, E. coli, Enterobacter sp., K. pneumoniae and Proteus vulgaris, has also been reported.

Molzahn V.A. et al. [26] conducted a systematic review of 22 articles to present current evidence on the antibacterial activity of ginger and its derivatives in order to develop perspectives for the treatment of infectious diseases caused by bacterial pathogens. Aqueous, ethanolic, and methanolic extracts of ginger, essential oils, and individual molecules, including gingerol and shogaol, have been shown to inhibit the growth of Gram–positive and Gram–negative bacteria, including multidrug–resistant (MDR) isolates, and to reduce various bacterial virulence factors, including biofilm formation [35]. A direct comparison of different ginger extracts showed that ethanolic and methanolic extracts exhibited stronger antibacterial activity against Gram–negative isolates, including E. coli, K. pneumoniae, P.aeruginosa, S. Typhi and S.sonnei, as well as Staphylococcus strains, compared to the aqueous extract of Zingiber officinale [26]. Another study reported better antibacterial activity of the aqueous extract compared to ethanolic and methanolic extracts when tested against S. aureus, K. pneumoniae and P. mirabilis [8].

It has been demonstrated that Zingiber officinale essential oils can effectively inhibit the growth of various Gram–positive bacteria, such as B. cereus and S. aureus, including MRSA, as well as Gram–

negative bacterial species, such as E. coli, S. Typhi, V. cholerae, A. Hydrophila, P. aeruginosa, and A. baumannii [38].

It has been found that the use of ginger together with other plant–derived compounds or synthetic antibiotics significantly enhanced the antibacterial activity of the latter [36]. In addition, ginger may also have immunomodulatory, including anti–inflammatory and antioxidant activities in vitro and in vivo. The authors concluded that ginger–derived compounds are promising alternative or adjunctive, antibiotic–independent options in the fight against infectious diseases caused by bacterial pathogens, including MDR strains [26].

In an experiment [6], the efficacy of ginger essential oil spray on Candida albicans (C. albicans) on self–hardening acrylic plates was studied. 120 self–hardening acrylic discs were contaminated with C. Albicans and randomly divided into four main groups: ginger essential oil exposure, nystatin (positive control), distilled water (negative control), and no exposure. The minimum inhibitory concentration (MIC) of ginger essential oil and nystatin was 1560 μg/ml and 4 μg/ml, respectively. It was demonstrated that the difference between the mean colony count of C. Albicans before (10175±1730.25) and after exposure to ginger essential oil (542.86±64.81) and nystatin (257.14±47.67) was statistically significant ($P<0.001$). The mean colony count of C. Albicans after topical application of nystatin was not significantly different compared to ginger essential oil ($P=0.204$). Nystatin and ginger essential oil were shown to be significantly more effective than distilled water at each time point ($P<0.001$). After 10 and 15 minutes, no significant difference was observed between the nystatin and ginger essential oil groups ($P=0.05$). The authors concluded that ginger essential oil spray demonstrated antifungal activity against C. albicans in the acrylic disc model.

One of the main uses of ginger is to treat and prevent colds, sore throats, and coughs, and to reduce inflammation [46]. Ginger has many beneficial properties. It has anti–inflammatory properties, making ginger tea extremely useful in treating mouth and throat conditions.

Other researchs have examined the use of ginger in the treatment of coronavirus disease 2019 (COVID–19) [2, 23, 40]. The results suggest that gingerol may inhibit viral replication by binding to the SARS–CoV–2 viral protein Nsp15. The viral nonstructural protein 15 (Nsp15) is increasingly being considered as an important therapeutic target for SARS–CoV–2 viral replication [23].

An in silico molecular docking investigation [2] investigated the potential of several bioactive compounds from ginger as anti–SARS–CoV2. Gingerenone A, gingerol, geraniol, shogaol, zingiberene, zingiberenol and zingerone were used as ligands for docking with S–protein and major protease (Mpro). Drug–like properties were also assessed using SwissADME. It was found that gingerenone A consistently had the lowest binding energy compared to the others with both S and MPro. However, gingerol, geraniol, shogaol, zingiberene, zingiberenol and zingerone are able to interact with key residues responsible for the catalytic domain of MPro, while geraniol, shogaol, zingiberene, zingiberenol and zingerone can affect the binding conformation of S–ACE2 and increase its binding energy.

Another study showed that ginger extract could be used as an adjunct to the treatment of COVID–19, as it demonstrated positive effects on acute respiratory distress syndrome (ARDS), pulmonary fibrosis, pneumonia, and sepsis, which also occur in COVID–19 patients [40].

Ginger is also used as a weight loss agent in obesity.

In an experiment [21], the effect of ethanolic extract of steamed ginger (SGE) (40 mg/kg and 80 mg/kg) for 12 weeks on obesity indices during a high–fat diet (HFD, 60 % fat w/w) was studied in a C57BL/6J mouse model with diet–induced obesity (DIO). It was found that ethanolic extract of steamed ginger significantly reduced lipid accumulation, suppressed adipogenesis and lipogenesis genes, and the expression of PPARγ and C/EBPα in 3T3–L1 cells and epidermal adipose tissue of DIO mice. PPARγ and C/EBPα are known to modulate the expression of aP2, GLUT4, fatty acid synthase (FAS), acetyl–CoA carboxylase (ACC), and adiponectin (ApN). Oral administration of ethanolic extract of steamed ginger significantly reduced obesity by significantly suppressing the expression of aP2, GLUT4, FAS, ACC, and ApN. In addition, mice fed ethanolic extract of steamed ginger on a high–fat diet showed significant reductions in total cholesterol and triglycerides compared to controls.

The immunometabolic effects of ginger (Zingiber officinale Roscoe) supplementation in obesity were reviewed by Preciado–Ortiz ME et al. [34]. Results from in vitro, in vivo, and clinical studies have shown that ginger and its major compounds, such as 6–gingerol and 6–shogaol, inhibit adipocyte differentiation and lipid accumulation, reduce proinflammatory cytokines including TNF–α, interleukin–6 (IL–6), and monocyte chemoattractant protein–1 (MCP–1), improve lipid profiles, and enhance anti–inflammatory adipokines such as adiponectin. Clinical studies have shown that ginger supplementation improves insulin sensitivity, reduces inflammatory markers, and controls body weight in obese individuals.

Thus, ginger supplementation showed immunometabolic effects with the potential to support the prevention and treatment of obesity and its comorbidities. The authors concluded that further clinical studies are needed to confirm the efficacy and safety of ginger (Zingiber officinale Roscoe) supplementation and its role in obesity treatment strategies.

The experimental study [1] examined the effects of ginger extract on diabetic cardiomyopathy in streptozotocin–induced diabetic rats. It was found that ginger extract administration reduced myocardial fibrosis and inflammation in diabetic cardiomyopathy, possibly by regulating the expression of genes encoding the SMAD/TGF–β pathway.

Veisi P. et al. [43] conducted a systematic review of experimental studies to investigate the renoprotective effects of Zingiber officinale extract on diabetic kidney disease. 41 articles that met the inclusion criteria were analyzed. Ginger supplementation was found to be associated with significant reductions in blood glucose levels in 28 studies. Nine studies showed significant reductions in malondialdehyde (MDA) levels after supplementation. 17 studies also showed reductions in serum creatinine. Fifteen studies reported reductions in total cholesterol, and 14 studies showed reductions in triglyceride concentrations. In 26 studies, ginger reduced diabetic kidney damage. The authors concluded that ginger had positive effects on blood sugar levels, lipid profiles, some inflammatory markers, oxidative stress, and pathological lesions in diabetic kidney disease. But well–designed clinical trials and meta–analyses are needed to confirm the results obtained.

A systematic review by Van B. et al. [42] analyzed the antidiabetic efficacy of Zingiber officinale and its compounds: gingerenone, gingerol, paradol, shogaol, and zingerone. It was demonstrated that in clinical studies, Zingiber officinale led to significant improvements in glycemic parameters (fasting blood glucose, hemoglobin A1C (HbA1c), and insulin resistance). In vitro and in vivo studies have established the mechanisms of action of the bioactive compounds of Zingiber officinale. In general, these mechanisms were to increase glucose–stimulated insulin secretion, sensitize insulin receptors, and increase glucose uptake, GLUT4 translocation. In addition, it was found that active ginger compounds inhibited the production of reactive oxygen species induced by advanced glycation end products, and also influenced the regulation of gene expression of liver enzymes associated with glucose metabolism, regulated the levels of pro–inflammatory cytokines, reduced the manifestations of pathological kidney lesions, contributed to the protective effect on β–cell morphology and the restoration of antioxidant mechanisms.

Crichton M. et al. [12] conducted a systematic review to determine the therapeutic effects and safety of any ginger species from the ginger family, taken orally, compared with any comparator or baseline data on any measure of health and well–being in humans. The analysis included 24 systematic reviews with 3 % overlap in primary studies. The strongest evidence was found for ginger's antiemetic effects in pregnant women (effect size: large; GRADE: high), analgesic effects in osteoarthritis (effect size: small; GRADE: high), and glycemic control (effect size: none to very large; GRADE: very low to moderate).

Ginger was also found to have a statistically significant positive effect on blood pressure, weight control, dysmenorrhea, chemotherapy–induced nausea and vomiting (effect size: moderate to large; GRADE: low to moderate), as well as on blood lipid profiles (effect size: small; GRADE: very low) and anti–inflammatory and antioxidant biomarkers (effect size: unclear; GRADE: very low to moderate). The authors noted that ginger at a dose of 0.5–3 g/day in capsule form for 3 months was effective. At the same time, significant heterogeneity and underreporting of interventions in clinical material were highlighted. This calls for randomized controlled and dose–dependent trials with sufficient sample size to standardize the routine clinical use of ginger.

This review was limited to the period of 5 years, and articles published in open-access sources. In addition, the heterogeneity of study designs, inclusion criteria, and diagnostic parameters of the selected publications significantly complicated the direct comparison of results.

Conclusions

1. Ginger has a long history of medicinal use. Numerous studies have shown that ginger contains nutritional components essential for health. Zingiber officinale Roscoe contains a variety of nutrients, such as carbohydrates, amino acids, proteins, vitamins, minerals, fatty acids, lipids, a large number of phytochemicals, especially essential oils and phenolic compounds and other biologically active compounds.

2. The biological activity of ginger and its chemical compounds is promising for the treatment and prevention of diabetes, nausea, vomiting, and inflammation. Research results have demonstrated potent antioxidant, as well as anti–inflammatory and antiemetic properties, pregnancy–associated nausea and vomiting of ginger compounds.

3. Findings from studies suggest that Zingiber officinale Roscoe supplements are beneficial for obesity and lipid metabolism disorders, but additional clinical studies are needed to support their efficacy and safety. It has been established that in patients with diabetes mellitus, the supplementation of Zingiber officinale had a positive effect on glycometabolic parameters, some markers of inflammation, oxidative stress, and the progression of kidney damage in diabetic kidney disease.

4. Research data indicate that ginger–derived compounds exhibit antibacterial activity against various bacteria, including clinically significant MDR pathogenic strains, and also enhance antimicrobial properties when combined with other natural compounds or synthetic antibiotics.

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Стаття надійшла 23.11.2024 р.