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Institute of Genetics and Animal Biotechnology
of the Polish Academy of Sciences, Jastrzębiec, Poland

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Zingiberaceae wonders: the antioxidant powerhouse for optimal health

Hemanth Kumar Boyina[1], Sohini Chakraborty[2], Omar M. Atrooz[3,4]*, Olga Adamska[5]*, Krishna Sanka[6], Atanas G. Atanasov[7,8,9], Artur Stolarczyk[10], Hanish Singh Jayasingh Chellammal[11], Vimal Arora[1], Kiran Gangarapu[12], Agnieszka Kamińska[13], Szymon Rybicki[14], Andrew Lockley[14]

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[1] University Institute of Pharma Sciences,Chandigarh University, Mohali-140413, Punjab, India

[2] School of Applied Sciences, Department of Biotechnology, Reva University, Bangalore-560064, Karnataka, India

[3] Department of Medical Laboratory Sciences, Faculty of Applied Medical Sciences, Al-Ahliyya Amman University, Amman 19328, Jordan

[4] Department of Biological Sciences, Mutah University. Mutah-Jordan

[5] Department of Ophthalmology, Collegium Medicum, Cardinal Stefan Wyszyński University, Wóycickiego 1/3 Warsaw, Poland

[6] Department of Pharmaceutics, School of Pharmacy and Technology Management (SPTM), SVKM's Narsee Monjee Institute of Management Studies (NMIMS), Deemed to be University, Shirpur-425405

[7] Ludwig Boltzmann Institute Digital Health and Patient Safety, Medical University of Vienna, Spitalgasse 23, 1090 Vienna, Austria

*Corresponding authors: omihandd@gmail.com; olgaadam98@gmail.com

[8] Laboratory of Natural Products and Medicinal Chemistry, Center for Global Health Research, Saveetha Medical College and Hospital, Saveetha Institute of Medical and Technical Sciences, Thandalam, Chennai, India

[9] Institute of Genetics and Animal Biotechnology of the Polish Academy of Sciences, Jastrzebiec, 05-552 Magdalenka, Poland

[10] Department of Orthopedics and Rehabilitation, Medical University of Warsaw

[11] Department of Pharmacology and Life Sciences, Faculty of Pharmacy, Universiti Teknologi MARA, Puncak Alam, Selangor-42300, Malaysia

[12] School of Pharmacy, Anurag University, Venkatapur, Ghatkesar, Medchal Malkajgiri District, Hyderabad, Telangana - 500088, India

[13] Department of Ophthalmology, Collegium Medicum, Cardinal Stefan Wyszyński University, Wóycickiego 1/3 Warsaw, Poland

[14] Collegium Medicum, Cardinal Stefan Wyszyński University, Wóycickiego 1/3 Warsaw, Poland

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A discrepancy between the production of reactive oxygen species [ROS] and the body's capacity to cleanse or repair the resulting damage is known as oxidative stress. Antioxidants shield cells against ROS and free radicals, which are extremely reactive because of their unpaired electrons, by preventing other molecules from oxidizing. Antioxidants from the Zingiberaceae family, which is well-known for its culinary and therapeutic applications, scavenge free radicals, chelate metal ions, alter enzyme function, and control gene expression. The antioxidant capacity of Zingiberaceae plant extracts and compounds is assessed using in vitro tests such as DPPH, FRAP, and ABTS. Animal research conducted in vivo clarifies these plants' bioavailability, metabolism, and impacts on diseases linked to oxidative stress. Lipid peroxidation, protein oxidation, DNA damage, and endogenous antioxidant defenses are examples of biomarkers of oxidative stress that shed light on the mechanisms behind Zingiberaceae antioxidant treatments and highlight their potential as a treatment for oxidative stress.

KEY WORDS: antioxidant activity / lipid peroxidation / oxidative stress / phenolic compounds

Oxidative stress: in a nutshell

The two main molecular effects of oxidative stress (OS) that we currently understand are damage to macromolecules and disruption of thiol redox circuits, which results in aberrant cell signaling and compromised redox regulation [Sies and Jones 2020]. Superoxide anions (O^{2-}), hydroxyl (HO), alkoxyl (RO), and peroxyl (RO_2) are among the oxygen-based radicals that cause OS. Other non-radical species that cause OS include hydrogen peroxide (H_2O_2), hypochlorous acid (HOCl), singlet oxygen ($^1O_2$), and ozone (O_3) [De Almeida *et al*. 2022]. Nitric oxide (NO), non-radical substances, peroxynitrite ($ONOO^-$), nitrogen dioxide (NO_2), and dinitrogen trioxide (N_2O_3) are examples of reactive nitrogen species (RNS), which are chemical molecules that can cause cellular damage through nitrosative stress [Griendling *et al*. 2016].

Antioxidants and Free radicals

The primary source of reactive oxygen species (ROS) is the mitochondrial electron transport chain, supplemented by other enzymatic processes and environmental influences. Occasionally, electrons impulsively reduce oxygen, resulting in the appearance of superoxide anions. Engaging cellular antioxidant defense systems is essential to regulate ROS levels and prevent oxidative damage. OS occurs in the situations of cumulative production of ROS that exceeds the organism's antioxidant defense capacity (Fig. 1). The organism's non-enzymatic defense system uses flavonoids, vitamins A, C, and E, glutathione (GSH), selenium, and β-carotene as a preventative strategy. Superoxide dismutase (SOD), glutathione peroxidase (GPX), catalase (CAT), peroxiredoxin (PRX), glutathione S-transferases (GST), glutathione reductase (GSR), and thioredoxin reductase (TRX) are additional components that contribute to the catalytic antioxidant system [Veskoukis *et al*. 2012, Benhar *et al.* 2018, Kirtonia *et al.* 2020].

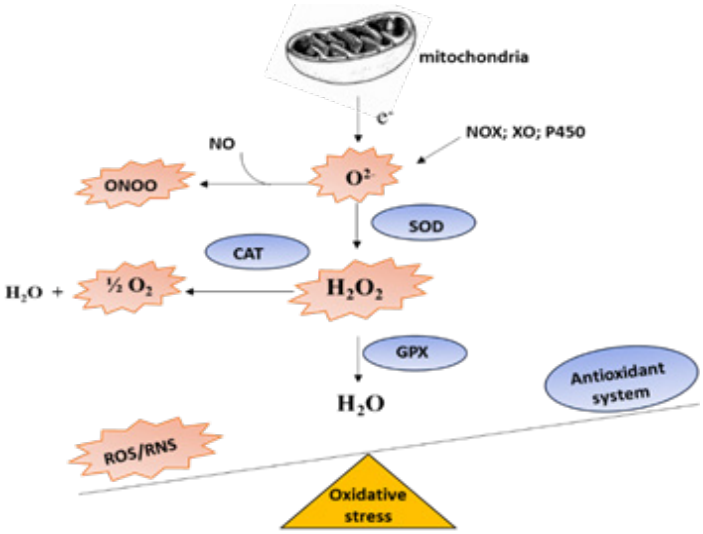

Fig 1. The main oxidative and antioxidant systems. Several enzymes, such as NADPH oxidase, xanthine oxidase and cytochrome P450 enzymes can produce ROS during their catalytic cycles. The key enzymes engaged in enzymatic processes include uncoupled endothelial nitric oxide synthase (eNOS), NADPH oxidase (NOX), xanthine oxidase (XO), arachidonic acid (ARA) and peroxidase [Zia *et al*. 2021].

Zingiberaceae antioxidants

The Zingiberaceae family, encompasses various species renowned for their medicinal and culinary applications. Figure 2 presents a comparison of antioxidant levels among well-known Zingiberaceae species, including ginger (*Zingiber officinale* Roscoe), turmeric (*Curcuma longa*), galangal (*Alpinia galanga*), and others, revealing

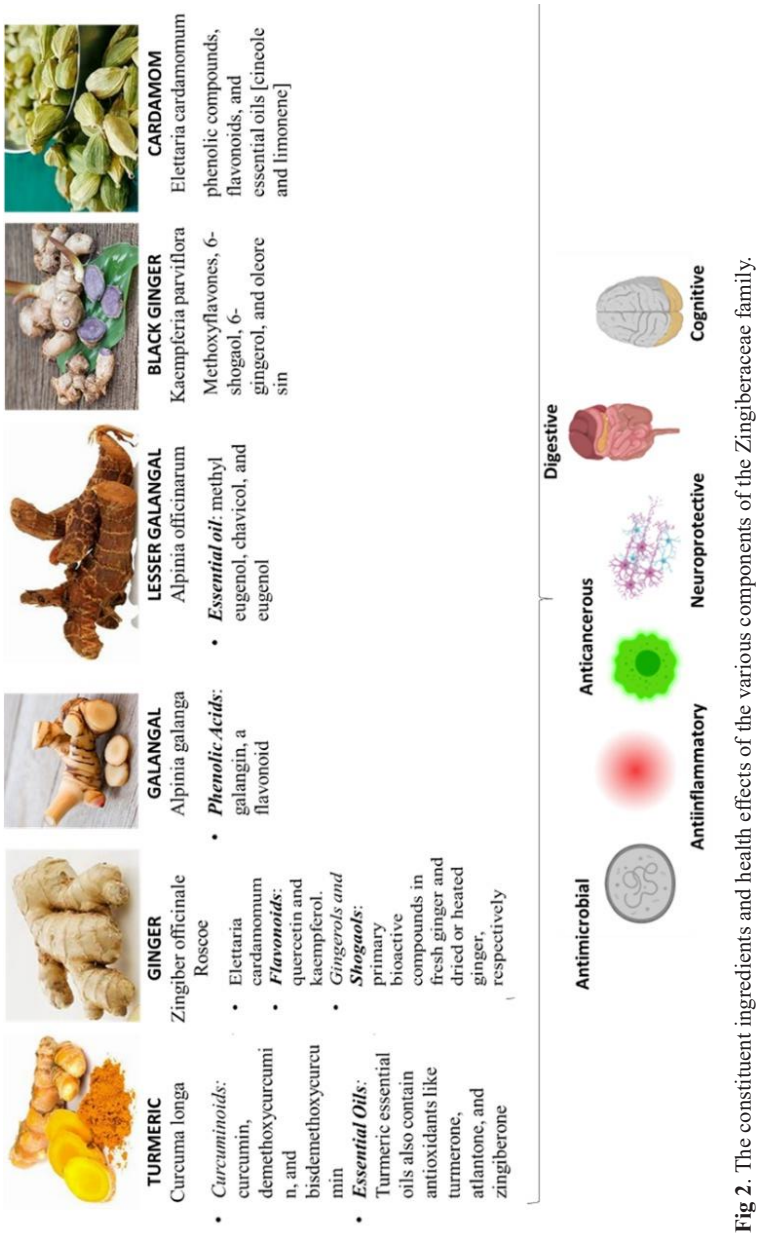

Fig 2. The constituent ingredients and health effects of the various components of the Zingiberaceae family.

that they exert their beneficial effects through diverse mechanisms. [Alolga *et al.* 2022, Hamidi *et al.* 2022, Van CHEN *et al.* 2022]. Awareness of the pathways helps people understand the health benefits associated with these plants [Semwal *et al.*

2015]. Integrating various Zingiberaceae-derived elements into one's daily diet can enhance overall health. [Cheah and Gan 2000]. Based on the initial scale, turmeric contains the highest concentration of phenolic compounds due to significant amounts of curcuminoids, followed by ginger with intermediate phenolic levels attributed to gingerols and shogaols, and galangal, which contains galangin (Fig. 2). Regarding flavonoid content, turmeric again tops the list among Zingiberaceae family members, containing compounds such as tumerone, zingiberone, and cardamom. Following turmeric are ginger and galangal, which possess a wide range of flavonoids including quercetin, kaempferol, and galangin. According to the final comparative analysis scale, turmeric distinguishes itself with its exceptionally high overall antioxidant capacity, primarily due to curcumin. Ginger follows turmeric, exhibiting strong antioxidant properties attributed to its gingerols and shogaols. Galangal ranks third, demonstrating moderate antioxidant capacity with its unique profile of phenolic compounds.

Antioxidant Mechanisms of Zingiberaceae Plants

Free Radical Scavenging. Free radicals are unstable molecules with unpaired electrons, which interfere with cellular functions. They neutralize free radicals by donating either electrons or hydrogen atoms and thus prevent further damage [Phaniendra *et al.* 2015, Tvrdá and Benko 2020].

Metal Chelation

The phenolic compound in the Zingiberaceae family of plants like ginger and turmeric comprises several groups, which include gingerol-shogaol and curcumin. Neutralized free radicals involve superoxide anions, hydroxyl radicals, peroxyl radicals, ROS, and RNS. Hydroxyl radicals from transition metals iron and copper in Fenton and Haber-Weiss reactions: Scavengers, capable of chelating these metal ions, prevent their involvement [Kehrer 2000, Jomova *et al.* 2012, Meyerstein 2021]. Phenolic compounds assist in the chelation of iron and copper, thereby inhibiting hydroxyl radicals and enzymes like XO [Limón-Pacheco and Gonsebatt 2009]. Antioxidants can modify gene expression involved in signaling pathways. Activation of Nrf2 results in its translocation to the nucleus, where it binds to ARE in DNA, enhancing the expression of antioxidant enzymes and protective molecules [Raghunath *et al.* 2018, He *et al*. 2020, Ngo and Duennwald 2022].

Gene Expression Modulation

Ginger and turmeric have been shown to enhance antioxidant enzymes like SOD and CAT, raise the levels of GSH, disturb lipid peroxidation pathways, lower the production of nitric oxide, and scavenge hydroxyl radicals. Ginger also suppressed iNOS and reduced caspase-3 positive cells, along with downregulation of TNF-α, which in turn scavenged the ROS production [Ballester *et al.* 2023]. It activated Nrf2 to elevate antioxidant levels. It prevented Bax, inhibited the activities of H2O2, MDA,

and MPO, and activated PI3K and Akt in B cells, thereby protecting against oxidative stress and inflammation [Ozkur *et al*. 2022]. The active components of ginger, the antioxidant compounds gingerols, flavonoids, and phenolic acids, contribute to its anticancer and antioxidant properties. [Alolga *et al.* 2022]. PI3K/AKT pathway is a significant pathway in regulating most cellular functions and is implicated in most cancers [Faes and Dormond 2015]. The ginger extract prevents the liver cells from getting damaged by hydrogen peroxide through the phosphorylation of AKT [Romero *et al.* 2018]. 6-gingerol inhibits the activity of xanthine oxidase (XO), reducing the formation of uric acid and harmful ROS [Eun *et al*. 2009].

Ginger extract is an active ingredient that actively fights chronic cell inflammation. It reduces pro-inflammatory markers such as mTOR, NF-kB, IL-6, TAC, CRP, and TNF-α. [Jalali *et al.* 2020]. It is reported that gingerols are capable of arresting the cell cycle; hence, they inhibit growth, reducing the size of a tumor because it upregulates CKDIs p21 that regulates progression from G1 to S phase; [Zadorozhna and Mangieri 2021], therefore, ginger extract works as an effective anticancer agent in human cells.

Free radicals cause damage to the phospholipid present in cell membranes by promoting lipid peroxidation. Antioxidants serve to combat this condition by neutralizing destructive free radicals [Halliwell and Chirico 1993, Yin *et al*. 2011, Valgimigli 2023]. Dangerous lipid peroxidation, thereby harmful in several respects, is prevented by the active ingredients of Zingiberaceae. Curcumin is an antioxidant agent that reduces ROS, removes advanced glycation end products, and inhibits lipid peroxidation [Alizadeh and Kheirouri 2019]. Curcumin activates SIRT1 and SIRT3 and inhibits the former, SIRT2. Its indirect antioxidant effects of SIRT1 and SIRT3 are protective; conversely, SIRT2 triggers pro-oxidative functions. SIRT1 decreases ROS via inhibition of protein 65; this blocks NF-κB signaling. In the nucleus, SIRT1 acts to activate FOXO3a and increases antioxidant genes CAT and SOD [Ballester *et al*. 2023]. Within the mitochondria, SIRT3 functions to help maintain cellular redox balance by activating the key enzymes [Lai *et al.* 2013]. Curcumin inhibited inflammation-related enzymes, which include COX-2 [Gangwar *et al*. 2025], lipoxygenase, adhesion molecules, and MMPs. The inflammation was efficiently suppressed due to the presence of ROS, whereas TLR4 expression is decreased as MAPK and NF-κB activation are inhibited in rat vascular smooth muscle cells [Vasanthkumar *et al.* 2019]. The major bioactive compounds in cardamom are 1,8-cineol and α-terpinyl acetate. The antioxidant activity decreases malondialdehyde (MDA), advanced protein oxidation products (APOP), and nitric oxide (NO) in the liver and plasma. Cellular antioxidants like CAT, SOD, and glutathione (GSH) also decrease oxidative stress. The cardamom group showed a marked reduction in CAT, SOD, and GSH activity [Rahman *et al.* 2017].

In vitro assays on antioxidant activity of Zingiberaceae plants

In vitro assays are essential tools for evaluating the antioxidant potential of plant extracts. The DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay measures the ability of antioxidants to neutralize the stable DPPH radical, causing a color change from purple to yellow [Barbosa and Peteros 2018]. Plant extracts are mixed with the DPPH solution, and the decrease in absorbance is measured spectrophotometrically [Baliyan *et al.* 2022]. Turmeric and black ginger exhibit high scavenging activity with IC50 values ranging from 1 to 5 µg/mL, while ginger, galangal and cardamom show moderate activity. The FRAP (Ferric Reducing Antioxidant Power) assay evaluates the capacity of antioxidants to reduce Fe3+ to Fe2+, resulting in a colour change. Plant extracts are combined with a ferric-tripyridyltriazine complex, and the increase in absorbance indicates reduced power [Benzie and Devaki 2017]. Turmeric and black ginger exhibit high FRAP values, whereas ginger cardamom and galangal show moderate activity [Vijayalakshmi and Ruckmani 2016]. Similarly, the ABTS assay assesses the reduction of the blue-green ABTS+ radical cation by antioxidants to a colorless form. Turmeric and black ginger demonstrate high activity with TEAC values >2 mM, while ginger, cardamom, and galangal show moderate activity [Arts *et al.* 2004]. The ORAC assay measures the ability of antioxidants to scavenge peroxyl radicals, quantified by the inhibition of fluorescence decay. Turmeric and black ginger have high ORAC values, while ginger, cardamom, and galangal range between 5,000-8,000 µmol TEAC/g [Arts et al. 2004]. Additionally, the Total Phenolic Content (TPC) assay uses the Folin-Ciocalteu reagent to determine phenolic content, expressing results as gallic acid equivalents [Middha *et al*. 2013]. Turmeric and black ginger exhibit high TPC, while ginger, cardamom, and galangal show moderate levels. The Total Flavonoid Content (TFC) assay, involving aluminum chloride, measures flavonoids expressed as quercetin equivalents (QE) [Shraim *et al*. 2021]. Turmeric and black ginger exhibit high flavonoid content, while ginger, cardamom, and galangal show moderate levels (Tab. 1).

Table 1. Comparison of antioxidant capacities of different Zingiberaceae species

Species	DPPH (IC50, µg/mL)	FRAP (µmol Fe^{2+}/g)	ABTS (TEAC, mM)	ORAC (µmol TEAC/g)	Total phenolic content (mg GAE/g)	Total flavonoid content (mg QE/g)
Turmeric (*Curcuma longa*)	1.2-4.8	high (600-900)	>2.0	9,000-12,000	high (80-120)	high (50-80)
Ginger (*Zingiber officinale*)	3.5-6.2	moderate (350-550)	1.2-1.8	6,000-8,500	moderate (50-85)	moderate (30-50)
Galangal (*Alpinia galanga*)	4.0-7.5	moderate (300-500)	1.0-1.5	5,000-7,500	moderate (45-70)	moderate (25-45)
Black Ginger (*Kaempferia parviflora*)	1.0-3.5	very high (>900)	>2.0	>12,000	very high (>120)	very high (>80)
Cardamom (*Elettaria cardamomum*)	5.0-9.0	low (200-350)	0.8-1.2	3,500-5,500	low (30-50)	low (15-30)

Decreasing IC50 values in DPPH indicate greater antioxidant activity. Increased values of FRAP, ABTS, and ORAC reveal increased antioxidant capacity. Phenolic and flavonoid contents are presented as gallic acid equivalents (GAE) and quercetin equivalents (QE), respectively.

In vivo assays on antioxidant activity of Zingiberaceae plants

In vivo, models for animal studies help solve the problem of how extract and chemicals from plants act in a living organism- their bioavailability, metabolism, and action on oxidative stress-associated disorders such as liver injury, diabetes, neurodegenerative diseases, colitis, arthritis, and hypertension. In rats orally administered with 100 mg/kg of ginger extract for four weeks, exposure to CCl4 resulted in liver damage that significantly impeded OS markers like MDA, though the content of antioxidants SOD and CAT remained high [Baliyan *et al.* 2022]. Various studies on Alpina galanga extract and isolated compound 1`δ-1`-acetoxyeugenol acetate administration in β-amyloid induced amnesia improved the synaptic plasticity and memory in mice [Hanish Singh *et al*. 2011ab, Jayasingh Chellammal *et al.* 2019]. Administration of the ginger extract for 8 weeks at 200 mg/kg significantly improved OS indices and lipid peroxidation in cardiac tissue, increasing the activity of GPx, heart fibrosis and inflammation in diabetic rats [Li *et al*. 2012]. Mice with Parkinson's were treated with curcumin [50 mg/kg] after 6-hydroxydopamine [6-OHDA] treatment for 4 weeks, significantly reduced OS indicators in the brain and increased antioxidant enzymes, with reduction of neuronal loss and improved motor skills [Li *et al*. 2012]. Curcumin (100 mg/kg) was administered to mice with dextran sulfate sodium (DSS)-induced colitis for 10 days, with a significant reduction of OS indicators and an increase in antioxidant enzyme activity in colon tissues [Guo *et al.* 2022]. Chronic alcohol exposure was administered to rats along with the galangal extract (200 mg/kg) for 6 weeks. The hepatoprotective activity of the galangal extract was investigated. The galangal extract showed a reduction in OS markers like MDA, with an increase in the activity of antioxidant enzymes in the liver tissues [Hemabarathy *et al.* 2009]. Rats with collagen-induced arthritis [CIA] were treated with galangal extract [100 mg/kg body weight] for 4 weeks, and there was a significant reduction in OS indicators while increasing the activity of antioxidant enzymes in joints [Raut and Shaji 2022]. Amyloid beta-treated mice received black ginger extracts (100 mg/kg), OS markers decreased, and levels of antioxidant enzymes increased for 8 weeks in their brain areas. Cognitive function improved by reducing amyloidβ-plaques accumulation [Temviriyanukul *et al.* 2023]. Cardamom extract (100 mg/kg) was administered to SHR for 12 weeks, in which OS indicators were reduced in blood and heart tissues [Yahyazadeh *et al*. 2021]. Ginger has well-documented chemical constituents, including gingerol and zingerone, that possess known activity for anti-inflammatory, antioxidant, and immunomodulatory properties. Ali *et al*. [2018], in their research, administered 6-gingerol in a dose range of 50 to 75 mg/kg for three weeks in mice. It was concluded that these mice had decreased blood glucose, oxidative stress, and improved insulin sensitivity [Ali *et al*. 2018].

Zingiberaceae-mediated OS biomarkers

Ginger, galangal black ginger, cardamom, and curcumin extracts significantly decrease Malondialdehyde (MDA) and Thiobarbituric Acid Reactive Substances (TBARS) in animal models to highlight reduced lipid peroxidation and OS [Aloliqi 2022, Razak *et al*. 2023]. The administration of Zingiberaceae also indicated protection of DNA via decrease in 8-OHdG and DNA breaks [Shamsabadi *et al.* 2023]

Other benefits

Ginger's derivatives have been evaluated for their antibacterial, antiviral, and antifungal properties [Mao *et al*. 2019]. Biofilms constructed by microbe's act as a strong defense against antimicrobials. Research conducted by Chakotiya *et al.* [2017]. Chakotiya *et al.* [2017] found that ginger demonstrates inhibitory effects on Pseudomonas aeruginosa (a multidrug-resistant strain) by disrupting membrane-building molecules and decreasing the ability to biofilm formation. Numerous last papers focused on ginger's anti-neuroinflammatory properties and plays an important role in memory formation, potentially aiding in the management and prevention of neurodegenerative diseases [Huh *et al.* 2018]. Some of the previous research studies highlighting the anticancer effects of curcumin and extracts from *Curcuma rhizome* and *Zingiber rhizome* concludes that *Curcuma rhizome* brings promising results against breast cancer and malignant melanoma [Rajimon *et al*. 2024, Danciu *et al.* 2015]. Further indicated that Ginger plays a protective role against cardiovascular disease according to numerous studies. Babaahmadi-Rezaei *et al.* [2020] study illustrated that Ginger played against atherosclerosis and balanced glucose metabolism throughout a significant decrease in lipoprotein (a) and fasting blood sugar (FBS) in patients with atherosclerosis supplemented with ginger [Babaahmadi-Rezaei *et al*. 2020]. Foshati *et al*. [2023] reported that Ginger consumption can improve gastrointestinal symptoms, decrease inflammation in the bowel, and alleviate motility [Foshati *et al.* 2023], and Ginger extract promoted the production of high-density lipoprotein (HDL) through enhanced production of lecithin-cholesterol acyltransferase ribonucleic acid (RNA) and apolipoprotein A-1 composed in the liver. Previous findings of a systematic review conducted by Lakhan *et al.* [2015] resulted in optimistic outcomes that indicate a significant influence of *Zingiberaceae* plants' extracts on subjective chronic pain decrease [Lakhan *et al.* 2015]. What is more, there is an evident linear dose-effect relationship, that suggests hypoalgesia from the extract can be adjusted to the intensity of the pain. Ginger can be served as an ingredient in food production and preservation to help maintain food quality [Offei-Oknye *et al*. 2015]. Utilizing ginger as a natural preservative during food processing and preservation can address these issues, potentially reducing food spoilage and eliminating factors that diminish shelf life. Using dried ginger or extracts for storing foods to prolong shelf life can affect the quality of processed and preserved items [Laelago Ersedo *et al*. 2023]. Products such

as ginger (*Zingiber officinale*), Javanese ginger (*Curcuma zanthorrhiza*), galangal (*Alpinia galanga*), and turmeric (*Curcuma longa*), that belong to the *Zingiberaceae* family, are widely used in cuisine and natural medicine as spices and medicines [Gupta *et al.* 2013].

Synergistic effects of Zingiberaceae compounds

Ilyas *et al*. [2024] experimented on animal models to check the synergistic effect of ginger and curcumin for anti-inflammatory potential [Ilyas *et al*. 2024]. The anti-inflammatory, analgesic and hemolytic potential of turmeric and ginger were evaluated using the Wistar rats and albino mice in an *in vivo* experiment. Anti-inflammatory activity was assessed using the carrageenan-induced rat paw edema Anti-nociceptive activity of the natural extract was conducted in comparison to the non-steroidal anti-inflammatory agent. The hemolytic activity was determined by preparing the plant extracts and checking against the control. Another study, conducted by Zhou *et al.* [2022] convinced the synergistic anti-inflammatory activity of Zingiberaceae compounds. The presented data concludes that the combination of ginger and turmeric extracts in ratios ranging from 4:6 to 8:2 influenced the pro-inflammatory molecules and decreased the overall response. The synergy of two bioactive compounds reduced lipopolysaccharide-induced, TNF, NO, and interleukins 6 expression.

Nanoformulatios- methods for optimization of beneficial effects

By enclosing bioactive compounds within a protective matrix, nanoencapsulation helps to safeguard their properties and extend their shelf life. The tries to improve the stability, bioavailability, and targeted delivery of Zingiberaceae plants' antioxidant activities have been made [Pateiro *et al.* 2021]. A new method was developed to create casein nanoparticles [NPs] loaded with curcumin or quercetin. These nanoparticles were formed by first binding the bioactive compounds to sodium caseinate, and then either reassembling the micellar structures or creating new casein NPs [Ghayour *et al*. 2019]. The method was appreciated for its high, ranging over 90%, entrapment efficiency, and protection of the hydrophobic micelles against fat-deprived beverages. Curcumin is considered to be utilized instead of synthetic polymer and may improve the pharmacokinetic properties of curcumin [Jayaprakasha *et al.* 2016]. Iqbal *et al.* [2020] concluded, that the solubility of curcumin in nanoemulsions was reaching the maximum in comparison to oil and water used as solutes. Those findings lead to the conclusion that such an important feature of natural ingredients as their stability can be enhanced using nanoemulsions [Iqbal *et al.* 2020].

Clinical trials validating the antioxidant and health benefits of Zingiberaceae plants

There are a few well-designed systemic reviews performed based on results observed in in vitro and animal studies, particularly for its antioxidative, analgesic, and anti-inflammatory effects and beneficial effects in the treatment of cardiovascular disorders. A meta-analysis on randomized controlled trials conducted by Zhang *et al.* [2022] evaluated the efficacy of influence of Zingiberaceae plants on cardiovascular risk in patients with coexisting type 2 diabetes mellitus (T2DM). Performed statistics revealed that Zingiberaceae plants can significantly reduce patients' body weight, and improve fasting blood glucose, glycosylated hemoglobin 1c, serum insulin, and homeostasis model assessment insulin resistance. Zingiberaceae supplements may be a promising adjuvant approach for treating T2DM and therefore preventing cardiovascular events. Rostamkhani H *et al*. [2022] [Rostamkhani *et al.* 2022] in their systemic review and meta-analysis of animal studies investigated the protective antioxidant effect of ginger extracts on acute kidney injury. The performed analysis revealed a significant impact of ginger extract supplementation on SOD, GSH, and CAT increase. Despite this, the supplementation enhanced the overall total antioxidant capacity. Hasani *et al*. [2019] in the systematic review and meta-analysis of clinical trials suggest that ginger supplementation reveals favorable effects on systolic and diastolic blood pressure in patients. Morvaridzadeh *et al.* [2021] present evidence that oral ginger supplementation brought significant improvement in oxidative stress parameters levels in patients. Authors support their findings with a significant increase in antioxidative markers: glutathione peroxidase activity, total antioxidant capacity, and a decrease in prooxidative marker: malondialdehyde, compared to control groups. Daily et al. [2015] in their systematic review examined the available research on whether ginger can effectively relieve primary dysmenorrhea. Randomized controlled trials included in the paper compared the analgesic potential of oral ginger supplementation compared to placebo by women suffering from primary dysmenorrhea. The authors declare conclusive evidence for the effectiveness in relieving the symptoms of dysmenorrhea.

Interaction with gut microbiome

Zingiberaceae compounds may modulate the gut microbiome and, therefore indirectly promote health in several ways. The bioactive compounds involved in the natural extracts from plants can selectively promote the growth of beneficial bacteria such as Bifidobacterium and Lactobacillus species while inhibiting the growth of potentially harmful bacteria. An animal model study conducted by Zhou *et al.* [2021] was shown that ginger supplementation increases the diversity of gut bacteria and alters the abundance of specific bacterial families, including Peptococcaceae and Helicobacter. This could help to improve the gut microbiota, which can be negatively

affected by early antibiotic use [Zhou *et al*. 2021]. Human gut bacteria can transform curcumin in various ways, creating new compounds with local and systemic effects. These compounds can be formed by altering the structure of curcumin or by removing certain chemical groups [Carmody *et al.* 2014]. Fermentation of Zingiberaceae polysaccharides by gut bacteria can lead to increased production of short-chain fatty acids like butyrate, acetate, and propionate, which have various health benefits [Kan *et al*. 2022].

Clinical relevance and translational challenges of Zingiberaceae antioxidants

Several reports indicate Zingiberaceae species possess great antioxidant activity, albeit difficult to translate clinically. Turmeric, ginger, and galangal have been promising in the management of disorders with oxidative stress such as cardiovascular disease, diabetes, and inflammation.

A meta-analysis of RCTs reaffirmed that ginger supplementation had a marked effect on decreasing blood pressure, cholesterol, and oxidative stress in patients with hypertension. Curcumin enhanced endothelial function and inflammation in cardiovascular disease patients. Curcumin and ginger supplements enhance insulin sensitivity, reduce fasting blood glucose, and increase antioxidant activity in diabetics. But variations in dosage and study design complicate comparisons.

Clinical trials of turmeric in Alzheimer's show improvement in cognition due to modulation of neuroinflammation and oxidative stress by curcumin. Low bioavailability of curcumin, however, restricts its therapeutic application. Turmeric and ginger inhibit pain and inflammation in patients with osteoarthritis and rheumatoid arthritis. They might be able to control inflammatory bowel disease (IBD) according to some evidence, though trials of a long-term duration are necessary to establish persistent benefits.

Limitations and research gaps

Though with promising outcomes, Zingiberaceae-derived antioxidants face challenges to widespread utilization.

Bioavailability issues

Curcumin, the active compound of turmeric, has poor bioavailability because of the rapid metabolism and poor absorption. Advanced delivery forms such as nanoparticles and liposomes have been studied to overcome the problem.

Variability in study design

Clinical trials vary by dosage, duration, and demographics, and hence it is challenging to formulate standard therapeutic guidelines.

Limited RCTs: Trials are predominantly small and narrow in scope, which compromises generalizability. Large multicenter RCTs are necessary to establish long-term efficacy and safety of Zingiberaceae antioxidants.

Potential interactions

Interactions are possible with curcumin and gingerols when using anticoagulants, antidiabetics, and chemotherapy agents. Clinical use may require cautious management.

Conclusion

Plants in the Zingiberaceae family, which includes well-known species including Zingiber, Curcuma, Alpinia, and Kaempferia, have a wide range of bioactive chemicals that make them potentially useful for pharmacotherapy. The anti-inflammatory, antioxidant, antibacterial, anticancer, neuroprotective, and cardioprotective qualities of these plants are attributed to their abundance of polyphenols, flavonoids, and essential oils. Their efficacy in treating ailments like metabolic disorders, neurological diseases, cardiovascular diseases, and numerous infections has been shown by research. Developments may improve the medicinal potential of substances produced from Zingiberaceae in molecular pharmacology, formulation techniques, and nanotechnology. Future research should concentrate on molecular insights, clinical validation, and drug development to fully utilize their medicinal potential for contemporary pharmacotherapy.

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