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REVIEW ARTICLE

A review on the ethnopharmacological importance and biochemical composition of medicinal plants within the Zingiberaceae family

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Abstract

The Zingiberaceae family, known for its diverse range of plant species, plays a crucial role in traditional medicine, culinary arts, and aesthetics across both developing and developed countries. However, the limited documentation of its medicinal uses presents a significant challenge. This review summarises the traditional therapeutic uses and physicochemical makeup of ten Zingiberaceae species. The study emphasizes the presence of bioactive chemicals, such as flavonoids and phenolics, in these plants. These compounds offer significant antioxidant, anti-inflammatory, and antibacterial advantages. Extensive literature searches were conducted using major academic databases to ensure the inclusion of the most relevant and up-to-date studies in the field. The review primarily concentrates on the extensively utilized rhizomes, while also examining the less-explored components of the plants, including leaves, stems, flowers, seeds, and fruits, which may possess significant value. Emphasis is placed on the antioxidant properties of the leaves and rhizomes, with a notable gap in research regarding the flowers and seeds. By examining their radical scavenging abilities, the review underscores the significance of these species in traditional medicine and their promising applications in modern healthcare and animal feeds. This exploration not only documents the traditional medicinal uses of these plants but also identifies gaps in current research, advocating for further investigation into the under-researched parts of the Zingiberaceae family. The findings suggest that expanding research on the antioxidant properties and traditional uses of flowers and seeds could reveal new potentials for these species in promoting human and animal health.

Keywords

antioxidants; ethnopharmacology; phytochemistry; public health; therapeutic application

Introduction

In underdeveloped countries, the use of medicinal plants to treat sickness has a long history that dates back thousands of years (1). One of the oldest recorded uses of therapeutic herbs dates back 5,000 years to the Sumerians (2). For 85-90% of people worldwide, traditional medicines are still the main source of healthcare today. This knowledge is crucial for directing current drug discovery efforts (3). Medicinal plants, a broad category with diverse properties, are abundant sources of therapeutic chemicals designed to address specific health issues (4). For millennia, these plants have been widely used to treat a variety of infectious diseases. Drug discovery from these plants is a complex process that combines phytochemical, botanical, and molecular techniques (5). Compounds derived from medicinal plants are well-known for their versatility; they are used as food additives, industrial ingredients, treatments for infectious diseases, and even in the environmentally friendly production of nanomaterials (4,6). Many active phytochemicals derived from these plants, including alkaloids, flavonoids, and proteins, as well as volatile essential oils found in culinary herbs, herbal teas, and spices, are antiviral in nature (5). It has been reported that secondary metabolites found in medicinal plants include alkaloids, sterols, terpenes, flavonoids, saponins, glycosides, cyanogenic, tannins, resins, lactones, quinines, and volatile oils (6). Throughout history, herbal medicine has played an important role in maintaining health and treating disease in cultures around the world. Technological advancements and an expanding body of research have reinforced herbal medicine's efficacy and sparked growing interest (7). As a result, global consumption of medicinal herbs is increasing, driven by rising demand for herbal treatments, natural supplements, and secondary compounds derived from them (8).

The Zingiberaceae, also referred to as the Ginger family, is a significant and commercially important family of flowering plants with a single seed leaf. The family is widely recognized for its widespread usage in both medical and culinary spices. It consists of around 1377 species distributed among 53 genera, and it thrives worldwide. The highest diversity of this family is found in the Malaysian regions, including Indonesia, Malaysia, Singapore, Brunei, the Philippines, and Papua New Guinea (9). Zingiberaceae species contain bioactive compounds such as phenolics and flavonoids, both of which have strong pharmacological properties. These compounds provide the plants with strong antioxidant, anti-inflammatory, and antimicrobial properties, making them extremely valuable for health promotion and disease treatment (10). These species are gaining popularity as medicinal herbs, with extensive research revealing antioxidant compounds in the rhizomes of numerous species in this family (10,12). Nevertheless, the therapeutic applications, physio-chemical composition, and antioxidant activities of these species have not been systematically organized to facilitate further investigation by the scientific community. Therefore, this review paper aims to thoroughly summarize and assemble the physiochemical composition, traditional medicinal uses, and antioxidant properties of ten selected plant species from the Zingiberaceae family. It explores entirely the antioxidant qualities of phytoextracts, highlighting research on the use of various Zingiberaceous plants for ethnomedicinal purposes. Key antioxidant characteristics such as flavonoid content, total phenolics, and the ability to scavenge radicals, like 2,2-diphenyl-1-picrylhydrazyl (DPPH), are extensively checked. The review places particular emphasis on the rhizomes and leaves, while also exploring the lesser-studied flowers and seeds. By expanding our understanding of these species' antioxidant potential and their roles in traditional medicine, this comprehensive evaluation opens new avenues for research and application in complementary medicine and public health. It also identifies gaps in current knowledge, especially regarding the antioxidant properties and traditional uses of flowers and seeds, suggesting areas for future investigation.

Materials and Methods

Multiple databases, including "Scopus," "Springer," "Google Scholar," "Wiley," "SciFinder," and "Web of Science," as well as dissertations, theses, books, and technical reports, were thoroughly searched for pertinent information. The carefully chosen publications were carefully scrutinized for compliance with the goals of the study, with an emphasis on their ethnopharmacological and phytochemical importance. Manual inspection was done on the references in each cited report. All publications released from January 2010 to December 2023 were included. Our keywords were “ethnopharmacological importance and Zingiberaceae family”; “medicinal plants and Zingiberaceae family” and “biochemical composition and Zingiberaceae family plants.”

Importance of Zingiberaceae medicinal plants

Zingiberaceae medicinal plants play a crucial role in traditional medicine practices worldwide, owing to their diverse ethnomedicinal uses and remarkable phytochemical activities (7). These plants have been employed for centuries in treating various ailments, including gastrointestinal disorders, respiratory problems, and inflammatory conditions (10). Their efficacy in folk medicine is attributed to the presence of bioactive compounds such as total phenolics and flavonoids, which exhibit potent pharmacological properties (11). Furthermore, Zingiberaceae plants possess significant free radical scavenging potential, which helps in neutralizing oxidative stress and reducing the risk of chronic illnesses like cardiovascular diseases and cancer (12). The exploration of their phytochemical constituents and ethnomedicinal uses underscores their importance in drug discovery and natural product research, highlighting their potential as sources of novel therapeutic agents with wide -ranging health benefits.

Ethnopharmacological uses of Zingiberaceae medicinal plants

Herbal remedies practices provide a valuable opportunity to make use of unaltered knowledge. Ethnopharmacology is the evolutionary process of understanding plant-based drugs or novel methods for semi-synthetic drugs. The absence of scientific data to support therapeutic uses is frequently a critical factor in this process (13). However, the approach focuses on the medicinal use of plants in various cultures. It employs interdisciplinary methods to validate traditional remedies and investigate their pharmacological prospects in modern medicine (14). The Zingiberaceae family displays diverse pharmacological characteristics, with numerous studies documenting the biological effects of its members. Table 1 provides a comprehensive overview of various plants from the Zingiberaceae family along with their respective parts used, bioactivities, and ethnobotanical uses. The rhizome of *Alpinia calcarata* Roscoe referred to as lesser galangal, is utilized for diabetes management and relief from respiratory issues. Pain relief, cancer, and parasite fighting, as well as support for digestion and kidney function, are facilitated by the whole plant (15-17). Rhizomes of *Alpinia malaccensis* Roscoe are used traditionally for treating nausea, vomiting, and wounds, and as a seasoning, showcasing antioxidant, antimicrobial, and anti-inflammatory effects. Essential oils from its leaves, pseudo stems, rhizomes, and fruits display moderate antimicrobial activity. Again, the preparations from its rhizome, fruit, and seeds accelerate wound healing, clarify the voice, relieve gastralgia with tympanites, and serve as a bath remedy for fever (18-20). *A. zerumbet*, also known as shell ginger, exhibits various bioactivities and ethnobotanical uses. It is utilized for its dual roles in cuisine as a flavor enhancer and in traditional medicine, particularly for potential cardiovascular benefits (21). Its rhizome and stem display anti-bacterial and antioxidant activity, while mature fruit finds application in treating heart diseases. Additionally, the leaf is commonly used in traditional cooking practices (22). *Amomum subulatum* Roxb, known as black cardamom, demonstrates antifungal and anticancer properties from its seed, whereas its whole plant is used for various ailments like respiratory issues, tuberculosis, and gastrointestinal disorders (23-26) (Table 1).

The rhizome of *Curcuma amada* Roxb, also known as Mango Ginger, serves multiple medicinal purposes. Traditionally used as an appetizer and alexiteric, it is also recognized for its antipyretic (fever-reducing) and aphrodisiac properties. Beyond these uses, it is employed in treating conditions like biliousness, itching, bronchitis, and asthma, and as a diuretic and emollient. Additionally, it acts as an expectorant and laxative, aiding in respiratory health and digestion. Another research indicates that *C. amada* exhibits notable antioxidant, anti-inflammatory, and antihyperglycemic effects (27, 28). *C. caesia*, commonly known as black turmeric, is utilized for various purposes. Its rhizome addresses piles and bronchitis, asthma, and epilepsy, managing tumors and leukoderma, providing relief from pox and bruises, treating joint diseases like rheumatism and arthritis, and aiding wound healing, tuberculous neck glands, and post-childbirth weakness (30-32). The rhizome of *C. longa*, commonly known as turmeric, is widely utilized in traditional and modern medicine for its extensive therapeutic properties. It is commonly employed to alleviate allergies, arthritis, and chronic diseases like Alzheimer's. Turmeric is also beneficial for treating various skin, respiratory, and gastrointestinal issues, providing pain relief, and supporting liver health. Beyond these applications, both the rhizome and other parts of the *C. longa* (30,34) plant exhibit potent antioxidant, anti-inflammatory, and hepatoprotective (liver-protecting) effects. Additionally, the plant is known for its antimicrobial capabilities and anticarcinogenic (cancer-preventing) properties, making it a versatile and valuable medicinal resource (32). (Table 1).

Extracts and essential oils derived from *Hedychium coronarium* Roxb have demonstrated a wide range of bioactivities. They possess significant antioxidant properties and have shown promise in antitumor and antidiabetic applications. Additionally, these extracts exhibit antiproliferative effects and serve as anthelmintic agents. They have been found effective in mosquito control as mosquitocidal and larvicidal agents and have shown antilithiatic properties, helping to prevent kidney stones. *H. coronarium* also displays chemopreventive potential, antiophidian (anti-snake venom) effects, and insecticidal capabilities. Furthermore, these substances have demonstrated efficacy as antifungal and antimicrobial agents, along with allelopathic effects that influence the growth of neighboring plants (33). The rhizome specifically demonstrates anthelmintic effects and neuro-pharmacological activity. It also shows fibrinogenolytic, coagulant, hepatoprotective properties, and larvicidal effects (35). *Kaempferia galanga* L., commonly known as galangal, exhibits medicinal properties primarily in its rhizome and leaf. These parts demonstrate antimicrobial, antioxidant, and anti-inflammatory effects, suggesting potential therapeutic applications for combating infections and inflammation-related conditions. Moreover, the rhizome of *K. galanga* serves multiple purposes beyond its medicinal properties, including acting as a snake venom antidote and vasorelaxant. Additionally, it finds use in culinary practices as a spice and in cosmetic and perfumery industries, indicating its versatility and widespread applications beyond traditional medicine (36, 37).

Zingiber officinale Roscoe, commonly known as ginger, offers a plethora of medicinal benefits across its various plant parts. Primarily, the rhizome is utilized in treating common colds, digestive disorders, rheumatism, cough, asthma, worms, and skin diseases, showcasing its broad therapeutic spectrum. Additionally, the rhizome is attributed to improving blood circulation, lowering blood lipids and sugar levels, relieving vestibular stimulation, and promoting digestion, indicating its multifaceted health-promoting properties. Beyond its medicinal uses, the whole plant of *Z. officinale* finds applications in cosmetics, toothpaste, and various foods, underlining its versatility and wide-ranging utility in everyday products and traditional remedies (38-41) (Table 1).

Antioxidant properties and radical scavenging potential of Zingiberaceae plants

Free radicals, comprising reactive oxygen species (ROS) and reactive nitrogen species (RNS), are produced endogenously or as a result of external factors, leading to damage in biomolecules and contributing to the progression of aging and various diseases, including cancer and cardiovascular conditions (42, 43). Enzymatic

Table 1. The ethnomedicinal uses of species under the Zingiberaceae family are listed below.

Scientific Name	Parts used	Bioactivity and ethnomedicinal uses	References
A. calcarata	Rhizome	Diabetes management; relief from respiratory issues, asthma, bronchitis; relief from arthritis.	(15)
	Leaf	Leaves are potent sources of analgesic, anxiolytic, and sedative compounds.	(16)
	Whole plant	Relieves pain; fights cancer and parasites; boosts digestion and kidney function; enhances vitality and voice; aids diabetes and respiratory issues.	(17)
A. malaccensis	Rhizome	Traditionally used for treating nausea, vomiting, and wounds, and as a seasoning agent. Exhibits pharmacological activities such as antioxidant, antimicrobial, and anti-inflammatory effects.	(18)
	Leaves, pseudo stems, rhizomes, and fruits	Essential oils extracted from the parts show moderate antimicrobial activity	(19)
	Rhizome, fruit, and seed	Accelerates wound and sore healing; enhances and clarifies the voice; provides relief from gastralgia accompanied by tympanites; serves as a bath remedy for individuals with fever.	(20)
A. zurumbet	Whole plant	Flavour additive, traditional medicine with longevity benefits, potential use against cardiovascular diseases like atherosclerosis.	(21)
	Mature fruit	Application in treating cardiovascular conditions.	(22)
	Leaf	Used in traditional cooking.	(22)
A. subulatum	Seed	Antifungal properties; anticancer properties.	(23)
	Whole plant	Respiratory ailments and tuberculosis; jaundice and hyperlipidemia; gastrointestinal disorders and lung congestions; inflammation; apoptotic cell impact.	(24, 25, 26)
C. amada	Rhizome	Appetizer and alexiteric; antipyretic and aphrodisiac; biliousness and itching; bronchitis and asthma; diuretic and emollient; expectorant and laxative.	(27)
	Rhizome and plant parts	Exhibits antioxidant, anti-inflammatory, and antihyperglycemic effects.	(28)
C. caesia	Rhizome	Addressing piles and bronchitis; asthma and epilepsy; managing tumors and leukoderma; providing relief from pox and bruises; treating joint diseases (rheumatism, arthritis) and wound healing; tuberculous neck glands and post-childbirth weakness.	(29, 30, 31)
C. longa	Rhizome	Used to treat allergies, arthritis, Alzheimer's, and chronic diseases, also applied for skin, respiratory, and gastrointestinal issues, pain relief, and liver disorders.	(30, 34)
H. coronarium	Rhizome and plant parts	Antioxidant, anti-inflammatory, hepatoprotective, antimicrobial, and anticarcinogenic properties.	(32)
	Rhizome and plant parts	Antioxidant, antifungal, allelopathic, antidiabetic, antiproliferative, antihelmintic, mosquitocidal, antimicrobial, larvicidal, antilithiatic, anti-ophidian, insecticide, chemo-preventive and antitumor agent	(33)
	Rhizome	Neuro-pharmacological, fibrinogenolytic, coagulant and hepatoprotective activities, larvicidal.	(35)
K. galanga	Rhizome and leaf	Antimicrobial, antioxidant, and anti-inflammatory.	(36)
	Rhizome	Snake venom antidote; vasorelaxant; used in spices, cosmetics, and perfumery.	(37)
Z. officinale	Rhizome	Common cold, digestive disorders, and rheumatism.	(38)
	Plant part	Improve blood circulation, lower blood lipids, lower blood sugar, relieve vestibular stimulation, and promote digestion.	(39, 40)
	Whole plant	Uses in cosmetics, toothpaste, and foods.	(40)
	Rhizome	Treats cough, asthma, worms, and other skin diseases.	(41)

antioxidant defenses, such as catalase and superoxide dismutase, along with low-molecular-weight substances like uric acid and vitamin E, play pivotal roles in counteracting oxidative stress (44). Numerous studies have explored the association between dietary phenolic compounds and flavonoids derived from fruits and vegetables and a reduced risk of degenerative diseases, highlighting the potential protective effects of these antioxidants (45).

Phenolic acids, a key subgroup of polyphenols abundant in plant-based diets, show promise in reducing the risk of neurodegenerative disorders. Studies have predominantly focused on their antioxidant potential, chelating metals, and neutralizing free radicals (46, 47). Extensive research confirms the ability of phenolic compounds from the Zingiberaceae family to influence gene expression, act as potent antioxidants, and potentially combat neurodegenerative disorders (12). In Table 2, a comprehensive examination of the total phenolic content within various plant species of the Zingiberaceae family is presented, offering valuable insights into the diversity of phenolic compounds across different plant parts. For instance, Melanathuru *et al*. and Singh *et al. found* that *A. Calcarata* exhibits noteworthy phenolic levels in both its leaf and rhizome, indicating potential health benefits associated with these plant parts (48, 49). Similarly, *A. malaccensis* demonstrates considerable phenolic content across multiple plant parts, suggesting a broad spectrum of potential therapeutic applications (50-53). In contrast, *A. zerumbet* showcases divergent phenolic levels among its rhizome, leaf, and flower (54-57) (Table 2).

Several studies found that *A. subulatum* exhibits differential phenolic levels between its leaves and fruits, with the latter displaying variations in phenolic content in both dry and extract forms (58-61). *C. amada* and *C. caesia* also demonstrate distinct phenolic profiles, particularly in their rhizomes, where variations are observed between dry weight and fresh weight measurements (31, 62-66). Furthermore, *C. longa* presents intriguing differences in phenolic content across different measurement methods, with notable variations between rhizome extracts and dry weight values (62, 67-69) (Table 2). Research on *H. coronarium* investigates the antioxidant properties of its rhizome, compares the antioxidant activity of extracts from both rhizome and leaves using IC_{50} values, and analyzes the phenolic content found in leaf and rhizome samples (70-72). The analysis of phenolic content in *K. galanga* reveals varying levels in both rhizome and leaf extracts, reflecting the distribution of these compounds throughout different parts of the plant. Notably, the leaf extract shows the highest concentration of phenolics among the entries for *K. galanga* (73-76).

Notably, the relatively lower phenolic content observed in *Z. officinale*, despite its widespread culinary and medicinal use, prompts further exploration into the specific bioactive compounds responsible for its renowned health benefits (77). Overall, the comprehensive analysis presented in Table 2 highlights the potential health-promoting properties of Zingiberaceae plants, offering valuable insights for further research and potential applications in traditional medicine and dietary practices.

Table 2. Phenolic contents of different Zingiberaceae medicinal plants.

Plant species	Plant parts	Total Phenolics content	References
A. calcarata	Plant parts	454.05 µg (GAE)/mg	(48)
	Leaf	59.25 ± 0.92 mg (GAE)/g	(49)
	Rhizome	37.75 ± 0.95 mg (GAE)/g	(49)
A. malaccensis	Leaf	59.25 mg (GAE)/g	(49)
	Leaf	76.25 mg (GAE)/g	(50)
	Flower	51.75 ± 0.2 µg (GAE)/mL extract	(51)
	Rhizome	36.1 ± 0.1 mg (GAE)/g dry extract	(52)
	Leaf	56.84 ± 0.37 µg (GAE)/mL extract	(53)
A. zerumbet	Rhizome	124.51 ± 0.57 mg (GAE)/g	(54)
	Leaf	20.1 ± 2.9 mg (GAE)/g	(55)
	Rhizome	199.77 ± 3.46 mg (GAE)/100 g DW	(56)
	Flower	56.7 ± 0.2 mg (GAE)/g extract	(57)
	Seed	13.7 ± 0.4 mg (GAE)/g extract	(57)
A. subulatum	Leaf	11.04 ± 0.2 (mg/g) GAE	(58)
	Fruit	35 ± 0.8 mg (GAE)/g DW	(59)
	Fruit	24.99 ± 0.25 mg (GAE)/g extract	(60)
	Fruit	4.11 ± 0.01 mg (GAE)/g extract	(61)
C. amada	Rhizome	92.30 ± 0.05 mg (GAE)/g	(62)
	Leaf	11.00 ± 0.29 mg (GAE)/g DW	(63)
	Rhizome	37.64 (TAE)/g DW	(64)
C. caesia	Rhizome	134.47 ± 0.06 mg (GAE)/g	(62)
	Rhizome	721.83 mg ± 3.82 (GAE)/100 g DW	(65)
	Rhizome	52.11 mg (GAE)/100 g DW	(31)
	Rhizome	60 ± 0.03 mg (GAE)/g DW	(66)
C. longa	Rhizome	260 ± 0.25 mg (GAE)/g	(62)
	Rhizome	155.31 ± 1.78 mg (GAE)/g extract	(67)
	Rhizome	18.14 ± 2.30 mg (GAE)/g DW	(68)
	Rhizome	32.57 mg (GAE)/g extract	(69)
H. coronarium	Rhizome	48.23 mg (GAE)/g DW	(70)
	Leaf	67.04 µg (GAE)/mg extract	(71)
	Rhizome	53.10 µg (GAE)/mg extract	(71)
	Leaf	1.95 mg (GAE)/g sample	(72)
	Rhizome	1.48 mg (GAE)/g sample	(72)
K. galanga	Rhizome	3.5 mg (GAE)/g DW	(73)
	Leaf	51.5 ± 0.67 mg (GAE)/g extract	(74)
	Rhizome	33.5 ± 0.84 mg (GAE)/g extract	(74)
	Rhizome	57.00 ± 7.07 mg (GAE)/g extract	(75)
	Rhizome	23.55 ± 0.5 mg (GAE)/g DW of extract	(76)
Z. officinale	Rhizome	7.70 ± 0.06 mg GAE/g DW	(77)
	Rhizome	6.15 ± 0.06 g GAE/100 g DW	(78)
	Rhizome	8.95 ± 0.63 mg GAE/g DW	(68)
	Rhizome	173.00 ± 8.29 mg GAE/100 g DW	(56)
	Flower	0.14 ± 0.01 mg GAE/g sample	(79)

The reviewed data reveals a diverse range of plant parts sampled, with rhizomes emerging as the most concerned across multiple entries (Fig. 1). Following the rhizome, leaves were an important consideration. Notably, the phenolic content of the flowers and fruits of several species, including *A. malaccensis*, *A. zerumbet,* and *A. subulatum*, was investigated (51, 57, 59-61). Except for *A. zerumbet*, no other species had its seed phenolics studied. Future research may explore the potential phenolic content of seeds, fruits, and flowers in additional plant species within the Zingiberaceae family.

Flavonoids, primarily stored in vacuoles but also found in chloroplasts and nuclei in certain species, possess antioxidant properties crucial for scavenging free radicals and reducing reactive oxygen species levels in plants. These compounds, as evidenced by references, play a significant role in enhancing plant defense mechanisms against oxidative stress, contributing to overall plant health and resilience (80, 81). The literature reviewed on flavonoid content in various Zingiberaceous medicinal plants, focusing on both fresh and dry extract compositions, reveals significant diversity in flavonoid concentrations across the species and plant parts, as summarized in Table 3. Previous studies suggest that *A. calcarata* and *A. malaccensis* exhibit consistent flavonoid levels in their rhizome and leaf extracts, with some variations in dry extract concentrations (48, 49, 52, 79, 82). In contrast, *A. zerumbet* demonstrates relatively low flavonoid content in its dried leaves but higher concentrations in rhizome and leaf extracts, as documented in references (56, 83, 84) (Table 3).

Again, *A. subulatum* predominantly exhibits flavonoids in its fruit, with concentrations varying in both fresh and dry extracts found by several studies (59-62, 85). Similarly, several studies also discovered that *Curcuma* species such as *C. amada*, *C. longa*, and *C. caesia* have diverse flavonoid profiles in their rhizomes, sometimes in leaf, with significant concentrations detected in both fresh and dry extracts (62, 63, 65-69, 86). Additionally, the reviewed data highlights notable quantities of quercetin equivalents in the rhizomes of *H. coronarium* and *K. galanga*, with comparatively lower levels observed in their respective leaves (68, 69, 78). These findings underscore the importance of considering both fresh and dry extract compositions in assessing flavonoid content in Zingiberaceous medicinal plants (Table 3).

DPPH may absorb an electron or a hydrogen radical, transforming from a free radical to a stable diamagnetic molecule. This method is frequently used to determine how well natural antioxidants can scavenge free radicals and DPPH (89). Table 4 presents key species from the Zingiberaceae family renowned for their ability to scavenge free radicals. The literature reviewed on the free radical scavenging potential of various Zingiberaceous medicinal plants provides valuable insights into their antioxidant activity, offering a foundation for understanding their therapeutic potential. Among the species investigated previously, *A. calcarata* emerges as a notable candidate, with its rhizome and leaf extracts demonstrating significant antioxidant properties (90-93).

Similarly, several studies suggest that *A. malaccensis* exhibits promising antioxidant activity,

Figure 1. Ethnopharmacological significance and biochemical composition of Zingiberaceae family plants.

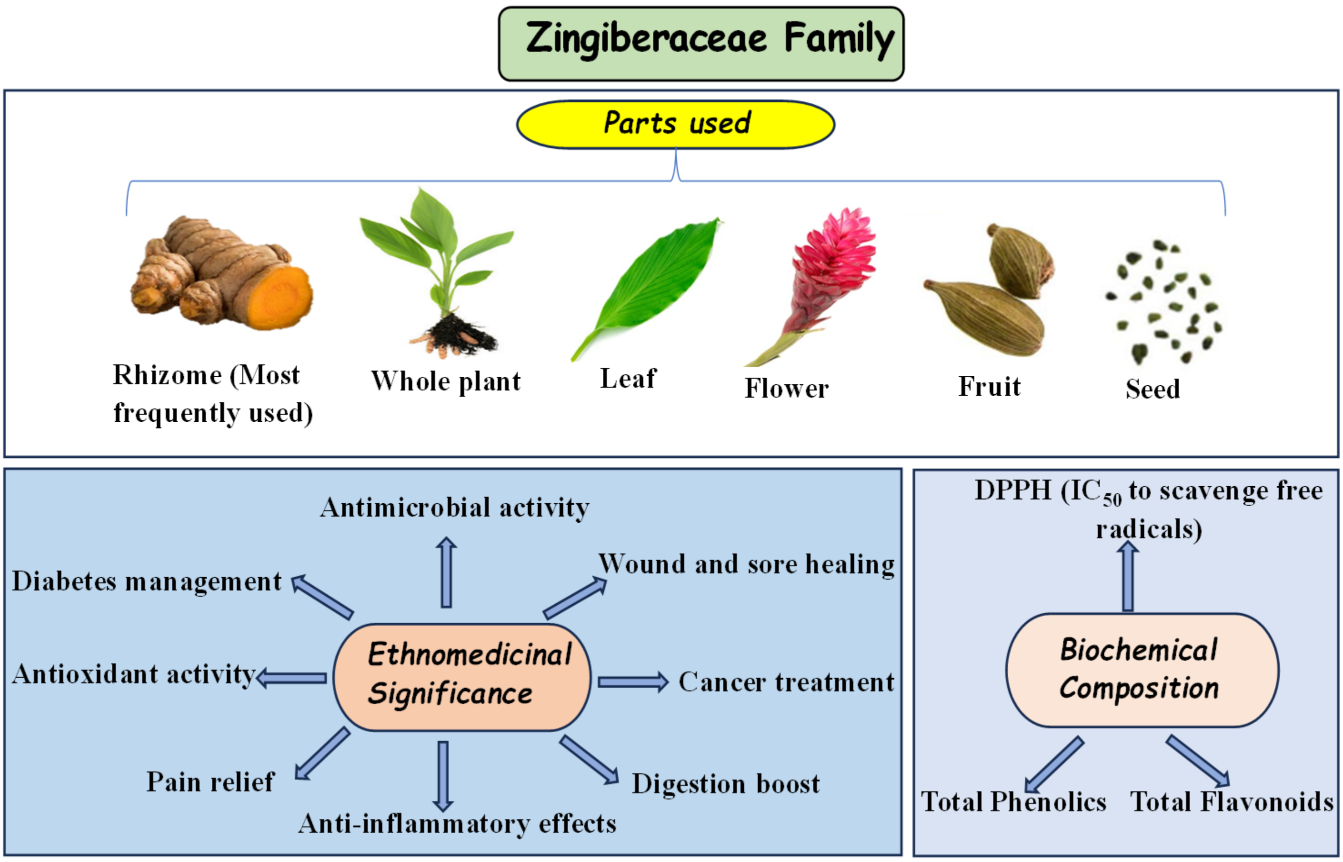

Table 3. Flavonoid contents of different Zingiberaceae medicinal plants

Plant species	Plant parts	Flavonoid contents	References
A. calcarata	Rhizome	36.34 (QE) µg/mg	(48)
	Leaf	38.38 ± 0.56 mg (QE)/g extract	(49)
	Rhizome	36.92 ± 0.24 mg (QE)/g extract	(82)
A. malaccensis	Flower	20.17 ± 1.15 mg (RE)/g	(79)
	Rhizome	13.0 ± 3.2 mg (QE)/g dry extract	(52)
A. zerumbet	Dried leaves	3.50 mg CE/g	(83)
	Rhizome	29.24 ± 0.31 mg (RE)/100 g DW	(56)
	Leaves	4.85 ± 0.05 mg (QE)/g DW	(84)
A. subulatum	Seed	0.0361% w/w	(85)
	Fruit	15.2 ± 0.6 mg (QE)/g DW	(59)
	Fruit	10.07 ± 0.21 mg (QE)/g extract	(60)
	Fruit	0.73 ± 0.01 mg (QE)/g extract	(61)
C. amada	Rhizome	22.52 ± 0.015 mg/g	(62)
	Rhizome	2.920 µg/100 mg extract	(86)
	Leaf	8.80 ± 0.03 mg (QE)/g DW	(63)
C. caesia	Rhizome	40.6 ± 0.1 mg/g	(62)
	Rhizome	271.57 ± 5.41 mg (QE)/100 g DW	(65)
	Rhizome	30 ± 0.06 mg/g DW	(66)
C. longa	Rhizome	151 ± 8.35 mg (QE)/g extract	(67)
	Rhizome	50 ± 5.80 mg (RE)/g DW	(68)
	Rhizome	279.87 mg (QE)/g extract	(69)
	Rhizome	64.23 ± 0.91 mg QE/g DW	(87)
H. coronarium	Leaf	47 ± 0.21 mg QE/g extract	(74)
	Rhizome	39.38 ± 0.75 mg QE/g extract	(74)
	Leaf	139.64 µg QE/mg extract	(71)
K. galanga	Rhizome	31.76 µg QE /mg extract	(71)
	Rhizome	37.72 ± 0.50 mg (CE)/g	(88)
	Rhizome	100 ± 1.414 mg (RE)/g dry extract	(76)
Z. officinale	Rhizome	9.52 ± 0.10 g (CE)/100 g DW	(78)
	Rhizome	2.65 ± 0.30 mg (RE)/g DW	(68)
	Rhizome	1.31 mg (QE)/g extract	(69)

particularly in its leaf and flower extracts (50-53). Conversely, *A. subulatum* displays strong antioxidant potential in its leaves and fruits, suggesting its efficacy in combating oxidative stress (Table 4).

Again, several studies found that *Curcuma* species, including *C. amada*, both rhizome and leaf extracts exhibited notable antioxidant activity, while *C. caesia*, particularly its rhizome, displayed significant antioxidant capabilities. *C. longa*, also show considerable antioxidant activity in their rhizomes and leaves, highlighting their relevance in traditional medicine (100, 63, 67, 86, 95-98). Furthermore, *H. coronarium* and *K. galanga* demonstrate antioxidant properties primarily in their rhizomes, contributing to their therapeutic value (Table 4). However, *Z. officinale*, commonly known as ginger, displays moderate antioxidant activity in its rhizome and flower extracts (56, 77, 79, 99). Overall, these findings underscore the importance of Zingiberaceous plants as potential sources of natural antioxidants and highlight the need for further research to explore their therapeutic applications in combating oxidative stress-related diseases.

The reviewed data affirms that each studied species within the Zingiberaceae plant family possesses a rich reservoir of potent antioxidant compounds and demonstrates impressive potential in scavenging harmful radicals. Notably, diverse plant parts, including leaves, rhizomes, fruits, seeds, aerial components, and occasionally even flowers, exhibit significant antioxidant attributes. While the bulk of research has focused on leaves and rhizomes, the antioxidant potential of flowers and seeds has received relatively limited attention.

Table 4. Free radical scavenging potential of different Zingiberaceae medicinal plants

Plant species	Plant parts	IC_{50} to scavenge free radical (DPPH)	References
A. calcarata	Rhizome	45 ± 0.4 µg/mL	(90)
	Leaf	336.643 ± 0.414 µg/mL extract	(91)
	Rhizome	411.866 ± 0.442 µg/mL extract	(91)
	Rhizome	84.54 µg/mL extract	(92)
	Rhizome	83.9%, 5.82 BHT/mL extract	(93)
A. malaccensis	Leaf	22.5 µg/mL	(50)
	Leaf	138.2 ± 1.7 µg/mL extract	(51)
	Rhizome	22.3 ± 0.2 µmol TE/g dry extract	(52)
A. zerumbet	Flower	83.28 ± 0.38 µg/ml extract	(53)
	Rhizome	122.14 ± 1.40 µg/mL	(54)
	Leaf	0.26 ± 0.04 mg/mL extract	(55)
A. subulatum	Leaves	8.25 ± 2.0 µg/mL	(58)
	Seed extract	78.26 ± 9.27%	(23)
	Fruit	149.8 ± 4.6 µg/mL extract	(59)
	Fruit	90.00 ± 1.00%	(94)
C. amada	Rhizome	56%	(95)
	Rhizome	Petroleum ether extract 18.98 ± 0.05%	(96)
	Leaf	127.70 ± 4.05 µg/mL extract	(63)
	Rhizome	63.69 µg/mL extract	(86)
C. caesia	Rhizome	156.4 ± 0.67 mg/mL extract	(67)
	Rhizome	67.36±0.76% extract	(100)
C. longa	Rhizome	40 ± 1.5%	(97)
	Rhizome	88.65 ± 0.6 mg/mL extract	(67)
	Rhizome	27.2 ± 1.1 µg/mL extract	(98)
H. coronarium	Rhizome	15.20 µg/mL	(70)
	Rhizome	20.11 µg/mL extract	(71)
	Leaf	10.33 µg/mL extract	(71)
K. galanga	Rhizome	>500.00 µg/mL extract	(75)
	Rhizome	1.824 mg/mL extract	(76)
	Rhizome	16.58 µg/mL extract	(88)
Z. officinale	Rhizome	4.26 ± 0.07 mg/mL	(77)
	Rhizome	15.23 µg/mL sun-dried sample	(99)
	Rhizome	9.35 ± 0.02 mg TE/g dried sample	(56)
	Flower	38.21 ± 0.81%	(79)

Conclusion

In conclusion, the comprehensive review of medicinal plants within the Zingiberaceae family highlights the extensive potential these plants hold for traditional medicine and therapeutic applications. The predominant utilization of rhizomes underscores their significance, while leaves and aerial parts also play a role in healing practices. However, the relatively limited attention given to leaves, flowers, seeds, and fruits suggests an area for further exploration and exploitation of these valuable resources. The rich reservoir of potent antioxidant compounds in these plants, particularly in plant parts and rhizomes, reaffirms their medicinal value. This thorough study states that the Zingiberaceous plant family holds promising potential for human well-being, offering exciting opportunities for future research and societal benefit.

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