

Native *Kaempferia galanga* L. in Vietnam: Biological Characteristics and Potential Applications for Human Health Care

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ABSTRACT: *Kaempferia galanga* is an important medicinal and economic herb of the Zingiberaceae family with significant potential for healthcare applications in Vietnam. This review was the first comprehensive synthesis focusing specifically on Vietnamese evidence regarding the botanical characteristics, cultivation practices, genetic resources, phytochemical composition, pharmacological activities, and traditional medicinal uses of this species. Available studies indicated that *K. galanga* was widely cultivated across Vietnam and demonstrated promising agronomic performance, with essential oil yields of 4.2–4.43% under optimized cultivation conditions and efficient in vitro propagation achieving 5.03 shoots per explant. Phytochemical investigations revealed a rich diversity of bioactive compounds, including ethyl p-methoxycinnamate, terpenoids, phenolics, flavonoids, and diarylheptanoids, which underpinned multiple biological activities. Experimental studies conducted in Vietnam demonstrated antioxidant, antifungal, anti-inflammatory, and uric acid-lowering effects, supporting its traditional use in treating digestive disorders, musculoskeletal pain, inflammatory conditions, and respiratory ailments. Given its local availability and pharmacological potential, *K. galanga* represented a promising medicinal resource for evidence-based herbal therapeutics and community healthcare in Vietnam. However, important gaps remained regarding chemotype standardization, clinical validation, and sustainable cultivation strategies. This review provided a scientific foundation for future pharmaceutical development, conservation, and effective healthcare utilization of *K. galanga* in Vietnam.

KEYWORDS: *K. galanga*; phytochemistry; pharmacology; traditional medicine; Vietnam; cultivation.

1. Introduction

Medicinal plants have long been recognized as important natural resources, contributing significantly to human health and environmental sustainability. Numerous studies have indicated that plants are rich sources of bioactive compounds, such as flavonoids, terpenoids, and phenolics, which possess considerable potential for pharmaceutical and healthcare applications [1]. In recent years, global interest in exploiting these compounds has increased

due to their biological activities, including anti-inflammatory, antioxidant, and antiviral effects [2]. In this context, species of the Zingiberaceae family have attracted considerable attention owing to their diverse chemical compositions and broad biological activities [3].

Kaempferia galanga L. is an herbaceous species of the Zingiberaceae family widely distributed across tropical Asia. This plant is commonly used in traditional medicine, culinary applications, and the fragrance industry. *K. galanga* is considered an important biological resource with considerable potential for sustainable utilization and biodiversity conservation [3]. Recent studies have reported that *K. galanga* contains a wide range of bioactive phytochemical constituents, notably ethyl *p*-methoxycinnamate (EPMC), ethyl cinnamate, flavonoids, and volatile essential oil components [4, 5]. Pharmacological investigations have demonstrated that this species exhibits multiple notable biological activities, including anti-inflammatory, analgesic, antioxidant, antibacterial, neuroprotective, and potential anticancer effects, largely attributed to these bioactive compounds [6, 7]. Owing to these properties, *K. galanga* shows considerable potential for applications in both traditional and modern medicine, particularly in supporting the management of inflammatory conditions, pain, infections, and the development of novel herbal therapeutic formulations [4, 8]. However, variations in genetic resources and chemical profiles among local populations may result in differences in bioactivity. This raises important questions concerning genetic diversity, ecological adaptability, and sustainable exploitation at the local level. Despite promising preclinical evidence, substantial research gaps remain. Current studies lack standardized data on chemical phenotypes according to ecological regions, large-scale clinical trials, and integrative approaches linking environmental factors to chemical composition variations [4, 9]. In addition, the absence of standardized cultivation and quality control procedures hinders the assurance of safety, efficacy, and sustainability of this medicinal resource.

In Vietnam, *K. galanga* is known by various local names and is widely used to treat digestive disorders, inflammation, pain, and respiratory diseases, consistent with ethnomedicinal reports of its expectorant, analgesic, and anti-inflammatory properties [9, 10]. However, despite its long history of use, scientific knowledge of this species in Vietnam remains fragmented across ethnobotanical records, phytochemical studies, and pharmacological research. Therefore, this study aims to provide a comprehensive review of *K. galanga* in Vietnam, focusing on its botanical characteristics, distribution, chemical composition, and pharmacological potential, while highlighting its relevance to human health and the environment. By synthesizing available evidence and identifying research gaps, this review contributes to a scientific foundation for sustainable utilization and effective application of this species in healthcare.

2. Botanical Characteristics and Distribution in Vietnam

In Vietnam, ten species of the genus *Kaempferia* have been documented [11]. *K. galanga* is recorded in traditional medical texts under several names, including “địa liên,” “son nại,” “tam nại,” and “củ thiên liên,” while the official pharmacological name is *Rhizoma Kaempferiae galangae*. This species is a perennial herbaceous plant propagated via rhizomes. The rhizomes develop into multiple small, ovate tubers growing close together, with an outer skin of yellow-brown to grayish-yellow, white to ivory flesh, a diameter of approximately 2–3 cm, a distinct aromatic odor, and a pronounced pungent taste. The plant typically has two leaves, occasionally three, which spread close to the ground; the leaf blades are oval, about 7–10 cm long and 5–7

cm wide, dark green and smooth on the upper surface, with a fine pubescence on the underside [11-13]. The flowers emerge from the rhizomes, are hermaphroditic, and exhibit white petals with a possible purple center. Inflorescences are usually enclosed in leaf sheaths or grow very low near the ground, distinguishing *K. galanga* from other Zingiberaceae species with tall pseudostems. Flowering primarily occurs from May to July, with the initial bud formation in March. Unlike many species such as *Kaempferia rotunda* or *Alpinia zerumbet*, *K. galanga* exhibits limited leaf color variation, and its leaf morphology is relatively more stable, reflecting its greater value as a medicinal plant rather than as an ornamental species [14]. As illustrated in Figure 1, the characteristic low-growing habit, limited leaf number, and aromatic rhizomatous structure distinguish *K. galanga* from other Zingiberaceae species with more developed pseudostems, supporting its taxonomic identification and medicinal recognition.



Figure 1. Morphological characteristics of *K. galanga* in Vietnam.

K. galanga grows in humid tropical regions, which are characteristic of Vietnam's climate. Figure 2 shows that *K. galanga* is distributed across multiple ecological regions of Vietnam. The species occurs wild in the northern mountainous provinces [13]. However, large-scale production is concentrated in northern provinces such as Hung Yen, Ha Noi, and Phu Tho; extends through the Central region, including Thanh Hoa, Nghe An, and Hue; and reaches some provinces in the Central Highlands and Southern regions, such as Gia Lai, Lam Dong, and Dong Nai [11, 12, 15]. Wild populations are relatively rare, as the species is primarily cultivated in household gardens or small-scale medicinal plant plots.

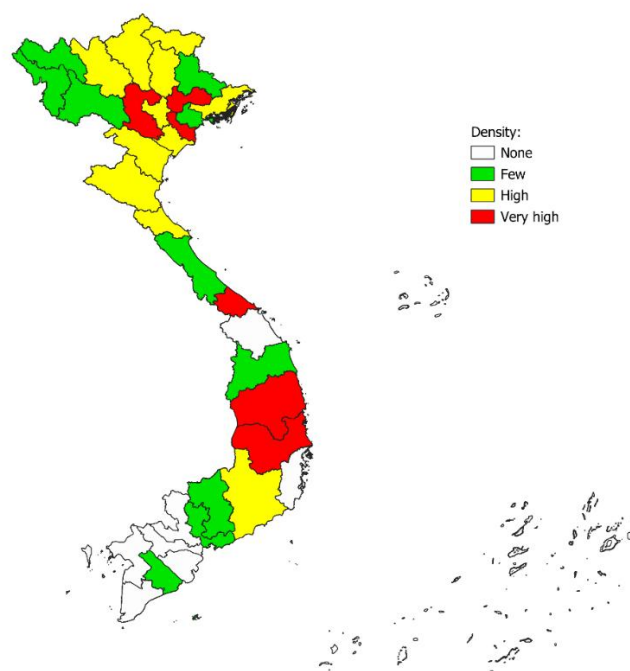


Figure 2. Distribution map of *K. galanga* in Vietnam.

3. Cultivation, Genetic Resources, and Sustainability

3.1. Cultivation practices in Vietnam.

In recent years, research and development of cultivation techniques for *K. galanga* in Vietnam have made considerable progress, particularly in the context of increasing demand for medicinal plants. However, in many areas, raw materials are still primarily sourced from the wild, often on a small scale and without systematic planning, leading to potential depletion of natural populations. Agronomic studies in Hué city indicate that *K. galanga* has a relatively long growth cycle, approximately 270 days from planting to harvest [16]. An important ecological characteristic for cultivation is its moderate drought tolerance but poor waterlogging tolerance, which requires well-drained soils. This trait is particularly relevant under Vietnam's tropical monsoon climate, where rainfall is unevenly distributed across seasons. Field experiments in Gia Lai have shown that planting at the beginning of the rainy season (around May) with a density of 125,000–166,000 plants per hectare yields the highest efficiency, producing 29.8–31.5 tons per hectare with essential oil content ranging from 4.20% to 4.43% [17]. Furthermore, the combined application of organic fertilizer and inorganic fertilizer in an appropriate ratio (3 tons of microbial organic fertilizer per hectare combined with NPK) has been demonstrated to improve yield and economic efficiency, achieving a value-cost ratio (VCR) of 4.54 [18].

3.2. Propagation techniques.

Propagation of *K. galanga* can be carried out using traditional methods through rhizomes; however, this approach is limited by slow multiplication rates and the risk of disease transmission. In this context, *in vitro* propagation techniques have been studied and applied in Vietnam to improve propagation efficiency and conserve genetic resources. Research has shown that using MS culture medium supplemented with 2 mg/l BA and 0.5 mg/l NAA results in the highest shoot proliferation, achieving an average of 5.03 shoots per explant after 4 weeks of culture [19]. Notably, this multiplication rate remains stable over multiple successive culture cycles, indicating high feasibility for large-scale seedling production. This method not only provides a uniform planting material supply but also plays an important role in *ex situ* conservation and supports studies on breeding and quality improvement of the medicinal resource.

3.3. Genetic diversity and germplasm resources.

The genetic resources of *K. galanga* in Vietnam exhibit a certain level of diversity, but they have not yet been fully studied or systematically documented at the national scale. Recent studies using ISSR molecular markers have analyzed the genetic diversity of samples collected from various regions, including Gia Lai, Me Linh (Ha Noi), Hiep Hoa (Phu Tho), Hue, and Dong Hy. Results indicate genetic similarity coefficients ranging from 0.59 to 0.97, reflecting variation among populations [12]. In addition, the application of DNA barcoding techniques has contributed to more accurate species identification, particularly in cases where confusion with other Zingiberaceae species may occur [11]. This approach is an important tool for building germplasm databases and supporting the management of biological resources.

4. Phytochemical Composition

Global phytochemical studies on *K. galanga* indicate that the dried rhizomes contain over 97 secondary metabolites, including 26 terpenoids (monoterpenoids, sesquiterpenoids, diterpenoids), 16 phenolic compounds, 8 diarylheptanoids, 16 cyclic dipeptides, 3 flavonoids, 11 fatty acids and esters, 9 polysaccharides, as well as some steroids, pyroglutamic acid, and other aromatic compounds [4]. In particular, EPMC and ethyl cinnamate are considered key bioactive compounds [4, 5, 20]. Terpenoids such as borneol, 1,8-cineole, camphene, and limonene have demonstrated antimicrobial and antioxidant activities [4]. Studies in Vietnam have also confirmed the richness of these compounds (Table 1). Phytochemical analysis of rhizomes collected in Ha Noi identified *p*-methoxy-*trans*-cinnamic acid and ethyl *p*-methoxy-*trans*-cinnamate [21]. These results are consistent with reports on the chemical composition of *K. galanga* from China, India, and Malaysia [4, 14, 20, 22]. Extracts from fresh and dried plant materials obtained via distillation yielded EPMC with extraction efficiencies of 1.12–1.99% and purities of 74–100% [23]. Another study reported total polyphenols of 54.42 mg GAE/g extract and total flavonoids of 56.96 mg QE/g extract from rhizomes [24]. The main constituents in the essential oil of *K. galanga* rhizomes included high contents of (E)-ethyl cinnamate (26.59%), EPMC (17.65%), and pentadecane (28.98%), together with other compounds such as borneol, 1,8-cineole, camphene, limonene, and various sesquiterpenoids ranging from 0.32% to 6.93% [25]. These findings highlight the chemical richness of *K. galanga* in Vietnam and provide a basis for its pharmacological applications.

Table 1. Phytochemical composition of *K. galanga* in Vietnam.

Sample and origin	Active compound	Quantitative content	Reference
Rhizome; Ha Noi	<i>p</i> -methoxycinnamic acid	-	[21]
Rhizome; Ha Noi	EPMC	-	[21]
Fresh plant material	EPMC	Extraction yield: 1.74%; purity: 100%	[23]
Dried plant material	EPMC	Extraction yield: 1.50%; purity: 100%	[23]
Dried plant material (Soxhlet, <i>n</i> -hexane)	EPMC	Extraction yield: 1.99%; purity: 95%	[23]
Dried plant material (Soxhlet, ethyl acetate)	EPMC	Extraction yield: 1.12%; purity: 74%	[23]
Rhizome extract	Total polyphenols	54.42 mg GAE/g extract	[24]
Rhizome extract	Total flavonoids	56.96 mg QE/g extract	[24]
Rhizome	EPMC	Not reported	[26]
Rhizome; Can Tho	Pentadecane	28.98%	[25]
Rhizome; Can Tho	(E)-Ethyl cinnamate	26.59%	[25]
Rhizome; Can Tho	EPMC	17.65%	[25]
Rhizome; Can Tho	δ -3-Carene	6.93%	[25]
Rhizome; Can Tho	1,8-Cineole	4.00%	[25]
Rhizome; Can Tho	Borneol	3.00%	[25]
Rhizome; Can Tho	Camphene	2.91%	[25]
Rhizome; Can Tho	Minor constituents (<i>Z</i> -7-tetradecene, α -pinene, cyperene, <i>n</i> -heptadecane, myrcene, limonene, cymene, γ -cadinene, valencene, β -pinene, β -elemene, tricyclene, α -humulene)	0.32–1.64%	[25]

5. Pharmacological Activities of *K. galanga* in Vietnam

K. galanga in Vietnam exhibits diverse pharmacological activities, including antioxidant, antifungal, anti-inflammatory, and uric acid-lowering effects (Table 2). These biological activities are closely associated with its phytochemical constituents, particularly EPMC, ethyl cinnamate, flavonoids, phenolic compounds, and volatile terpenoids [4,5]. Antioxidant activity

is likely attributed to phenolic and flavonoid compounds, which can scavenge free radicals, donate hydrogen atoms, and reduce oxidative stress [4, 24]. This is consistent with the observed DPPH and ABTS radical scavenging activities, as well as the enhanced oxidative stress tolerance in *Drosophila melanogaster* fed with rhizome extract [24]. The uric acid-lowering effect may be related to inhibition of xanthine oxidase, a key enzyme involved in uric acid biosynthesis. Since the active fractions in the Vietnamese study were selected based on preliminary xanthine oxidase inhibitory screening, this suggests that cinnamate derivatives and phenolic constituents may contribute to the antihyperuricemic effect [27]. The antifungal activity appears to be mainly associated with EPMC and volatile essential oil constituents such as 1,8-cineole, borneol, camphene, and limonene [4, 25]. EPMC showed inhibitory activity against *Candida albicans* [26], while essential oils completely suppressed *Rhizoctonia solani* and *Sclerotium rolfsii*, accompanied by hyphal shrinkage and deformation observed by SEM [25]. These effects may result from disruption of fungal cell membrane integrity, altered membrane permeability, and interference with fungal metabolism [4]. In addition, international studies have reported anti-inflammatory and analgesic effects of *K. galanga*, particularly linked to EPMC through modulation of inflammatory signaling pathways, including suppression of NF- κ B and COX-2 expression [4,6]. Although direct Vietnamese mechanistic evidence remains limited, these findings provide pharmacological support for the traditional use of *K. galanga* in managing pain, inflammation, and musculoskeletal disorders [30].

Table 2. Pharmacological studies of *K. galanga* in Vietnam.

No.	Model and Method	Key Findings	Reference
1	In vitro: DPPH, ABTS, RP; In vivo: <i>Drosophila melanogaster</i> under H ₂ O ₂ and paraquat stress	EC ₅₀ DPPH 151.6 ± 2.5 µg/ml; ABTS 2404.8 ± 55 µg/ml; RP 116.5 ± 4.8 µg/ml; flies fed with rhizome extract showed enhanced tolerance to oxidative stress	[24]
2	Swiss mice with hyperuricemia induced by 500 mg/kg potassium oxonate; compared with allopurinol; fractions selected after preliminary in vitro xanthine oxidase inhibition	Uric acid levels decreased from 21.03 mg/dl in the model group to 16.50 mg/dl at 100 mg/kg and 15.85 mg/dL at 300 mg/kg, corresponding to reductions of 21.54% and 24.63%, respectively	[27]
3	In vitro modified EUCAST assay on six <i>Candida albicans</i> strains, including 2 fluconazole-sensitive and 4 resistant strains	IC ₅₀ approximately 90.1–105.3 µM on 2 sensitive strains and 1 resistant strain; IC ₅₀ could not be determined (3–300 µM) for the remaining 3 resistant strains	[26]
4	In vitro: Antifungal analysis against <i>R. solani</i> and <i>S. rolfsii</i> using <i>K. galanga</i> essential oil	<i>K. galanga</i> EO completely inhibited <i>R. solani</i> at 312 ppm (99.71 ± 0.29%) and <i>S. rolfsii</i> at the same concentration (99.52 ± 0.48%); SEM observations showed hyphal shrinkage and deformation	[25]

6. Traditional Medicinal Uses and Healthcare Applications

In traditional medicine, *K. galanga* has been used for centuries. In China and several other Asian countries, it is employed to treat common colds, dry coughs, abdominal pain, muscle pain, and rheumatism, while also promoting digestion and analgesia [28]. In India and Malaysia, the plant is used for treating diarrhea, inflammation, swelling, gastrointestinal disorders, and postnatal care [29]. In traditional Vietnamese medicine, *K. galanga* is commonly used to alleviate indigestion, cold-related abdominal pain, edema, numbness, headaches, diarrhea, and whooping cough [30]. Some formulated products based on *K. galanga* are used to relieve musculoskeletal pain, reduce inflammation, and decrease edema. In addition, alcohol-infused preparations of *K. galanga* are widely applied topically to massage affected areas, helping to reduce numbness and body aches.

7. Limitations, Safety Concerns, and Toxicity

Despite its promising pharmacological potential, the medicinal use of *K. galanga* still has several limitations and safety concerns. First, most available evidence has been derived from *in vitro* experiments or animal models, while clinical studies in humans remain very limited. Therefore, the therapeutic efficacy and appropriate dosage of *K. galanga*-based preparations have not yet been fully established [4, 9]. In addition, variations in plant origin, cultivation conditions, harvesting time, extraction methods, and chemical composition may influence the levels of major bioactive compounds such as EPMC, ethyl cinnamate, terpenoids, phenolics, and flavonoids, leading to differences in biological activity and safety profiles [4, 5, 20]. Toxicological data are also insufficient. Some studies have suggested that *K. galanga* extracts may exhibit low acute toxicity at tested doses, but comprehensive evaluations of chronic toxicity, reproductive toxicity, genotoxicity, herb–drug interactions, and long-term safety remain lacking [4, 27]. In Vietnam, the *n*-hexane extract of *K. galanga* was evaluated for acute and subchronic toxicity, supporting its short-term experimental safety; however, these findings cannot replace clinical safety assessments in humans [27]. Moreover, because *K. galanga* contains bioactive essential oil constituents and cinnamate derivatives, inappropriate dosage or prolonged use may potentially cause adverse effects, irritation, or interactions with conventional medicines, especially in vulnerable groups such as pregnant women, children, older adults, and patients with chronic diseases [4, 9]. Therefore, although *K. galanga* has long been used in traditional medicine and has demonstrated promising pharmacological activities, its medicinal application should be supported by standardized raw materials, quality control of active compounds, dose standardization, and further toxicological and clinical studies. These measures are necessary to ensure the safe, effective, and evidence-based use of *K. galanga* in healthcare.

8. Conclusion

K. galanga is an important medicinal and economic herb with considerable potential for healthcare applications in Vietnam. Its rich phytochemical composition, including phenylpropanoids, terpenoids, phenolics, and flavonoids, underpins diverse biological activities such as antioxidant, antifungal, anti-inflammatory, and uric acid-lowering effects. Cultivation and propagation studies in Vietnam demonstrate the feasibility of large-scale production. However, several important research gaps remain. Future studies should prioritize well-designed clinical trials to validate therapeutic efficacy, establish appropriate dosage regimens, and confirm long-term safety in humans. In addition, chemotype characterization and standardization across different ecological regions of Vietnam are needed to ensure consistent phytochemical quality and reproducible pharmacological activity, particularly for key marker compounds such as EPMC. Research should also focus on developing standardized cultivation protocols and sustainable harvesting strategies, including germplasm conservation, propagation improvement, and environmentally responsible production systems, to support both medicinal applications and biodiversity conservation. Addressing these priorities will facilitate the evidence-based development of *K. galanga* as a safe, effective, and sustainable medicinal resource.

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Author Contribution

Do Thi Dinh: Conceptualization, Methodology, Writing; Le Minh Ha: Data Collection; Supervision; Bui Thi Thuy Luyen: Review and editing, Data Analysis.

Competing Interest

The authors declare no competing interests.

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