

Profile of chemical compounds and potency of galangal (*Kaempferia galanga* L.) essential oils from Kemuning Village, Karanganyar District, Central Java, Indonesia

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Abstract. Muzzazinah, Yunus A, Rinanto Y, Suherlan Y, Ramli M, Putri DS, Ningtyas DW, Rahma AL, Nabila SJ. 2024. Profile of chemical compounds and potency of galangal (*Kaempferia galanga* L.) essential oils from Kemuning Village, Karanganyar, Central Java, Indonesia. *Biodiversitas* 25: 1386-1393. Kencur or galangal (*Kaempferia galanga* L.) belongs to the Zingiberaceae family, which is known to contain essential oils. *K. galanga* essential oil is commonly used as a traditional medicine, one of which is to treat inflammation. This study aims to analyze the chemical content of the essential oil of *K. galanga* from Kemuning Village and their known bioactivities. The material used was essential oil from the distillation of *K. galanga* rhizome, which is the waste product of Kemuning essential oil production. Gas Chromatography-Mass Spectrometry (GC-MS) was applied to analyze the chemical content of *K. galanga* essential oil. The results showed that the phytochemical content of *K. galanga* essential oil compounds were Pentadecane: 36.64%, Cypereene: 1.16%, Alpha-gurjunene: 1.04%, Heptadecane: 1.24%, 8-Heptadecane: 1.68%, Gamma-Murolene: 1.55%, (2,2)-3,6-Nonadienal: 2.41%, Ethyl (2E), 3-Phenyl-2-Propenoate: 16.02 %, Ethyl P-Methoxycinnamate: 6.36%, and Ethyl P-Methoxycinnamate: 25.54%. This study shows that *K. galanga* is a good source of phytoconstituents used as industrial raw materials to produce medicines, perfumes, and flavoring ingredients.

Keywords: *Kaempferia galanga* L., phytoconstituents, profile

INTRODUCTION

As in several tropical countries, plants have been used as traditional medicines for generations in Indonesia. Traditional and modern medical therapy and medicine are developed based on ancient medicine to cure and prevent diseases. Several synthesized drugs are derived from various plants, which are vital in the chemotherapy drugs industry worldwide (Khan and Ahmad 2019).

The diversity of medicinal plants in Indonesia is relatively abundant, and exploration of its potential to cure critical illness has been done continuously (Elfahmi et al. 2014; Illian et al. 2021; Pertiwi and Atun 2022). Moreover, scientists worldwide are constantly exploring the potential of the natural pharmacological constituents of the bioactive compounds present in medicinal plants (Srivastava et al. 2019; Fajriyah et al. 2023). Studies also reveal that 80% of the world's population depends on herbal medicines because of their high potency in fighting disease, lower side effects, non-narcotic properties, and cost-effectiveness (AlSalhi et al. 2020). However, the research should be critically run on the diversity of the chemical compound, which is assumed to be influenced by the biogeographical diversity of the plants.

Research on the potential of *Kaempferia galanga* L. (kencur or galangal) as a cooking spice and medicine is related to its secondary metabolites. Plants produce secondary metabolites to fight various pathogens, such as insects, bacteria, fungi, nematodes, and herbivores. Plants produce secondary metabolites to adapt or defend in an unfavorable environment. Secondary metabolites used as a plant defense mechanism also play a significant role in curing human diseases. Alkaloids, phenolic compounds, and terpenoids are plants' primary secondary metabolites. Essential oils are a group of terpenoids, especially monoterpenoids, and sesquiterpenoids, which easily evaporate at room temperature and have a distinctive aroma.

Kaempferia galanga is a common spice that improves food flavor and has good potential for pharmacological activities. However, the same plant species do not always contain the same metabolite compounds. The active substances in the same species may differ in type, contents, and concentrations. These differences are caused by the differences in the environment of the plant and may influence the interaction between plants and the environment in a long evolution process. The influence of biotic and abiotic factors may shift the metabolic pathways of the plants to produce certain secondary metabolite compounds (Van De Velde et al. 2019). Therefore, the secondary metabolites in

a plant are specific and strongly affected by environmental conditions. Production of certain bioactive substances in plants may significantly increase or decrease under particular environments.

Kaempferia galanga (Zingiberaceae) family is a rhizome plant with extraordinary medicinal activity. In Java, this plant *K. galanga* is used as a food flavoring, an expectorant, body resistance, and external medicine as *pilis* (a natural concoction which is placed on the forehead to improve blood circulation and provide calm feeling) or *param* (powder slurry which is rubbed to reduce pain). Several industries require rhizome extracts of *K. galanga* for drug development and perfume manufacturing (Khairullah et al. 2021). In addition, *K. galanga* leaves have been used extensively for preparing mouthwash, food flavorings, hair tonics, and various other applications.

Ethnobotanically, *K. galanga* is commonly used as a medicine for diarrhea, cough, fever, and rheumatism, and it relieves stomach ulcers. It has been proven that *K. galanga* is efficacious in curing several diseases. The use of *K. galanga* in traditional medicine is related to its bioactive compounds, especially its essential oil. Essential oils have long been used as aromatherapy, antimicrobial, and for treating hypertension.

The Gas Chromatography-Mass Spectrometry (GC-MS) method is powerful for analyzing aromatic compounds in various samples, including aromatic ginger. GC-MS is a two-step analytical technique that combines Gas Chromatography (GC) with Mass Spectrometry (MS). Gas chromatography separates the mixture of compounds, while mass spectrometry identifies and quantifies individual compounds based on their mass-to-charge ratio. Gas chromatography and mass spectrometry are combined to identify qualitative and quantitative compounds.

Several previous research have identified active compounds in *K. galanga*. The main compounds of *K. galanga* essential oil from Medan differed from *K. galanga* from Guangdong (China). Based on the results of the

GCMS analysis, the primary compounds in *K. galanga* from Medan were limonene (2.39%), borneol (13.23%), and ethyl ester (78.35%) (Simangunsong and Surbakti 2023). Meanwhile, the primary compounds in *K. galanga* from Guangdong consisted of trans ethyl p-methoxycinnamate (32.01%), n-pentadecane (29.14%), and trans ethyl cinnamate (19.50%) (Wang et al. 2023). The differences in composition and concentration of the compounds are due to the differences in habitat, which influence the biochemical synthesis pathway of the compounds. The secondary compounds in plants are unique because they depend on the plant's biotic and abiotic factors. However, research on the chemical compounds of *K. galanga* from the Kemuning region has never been reported yet. This study aims to determine the phytochemical content of *K. galanga* planted in the Kemuning area, Central Java, using Gas Chromatography-Mass Spectrometry (GC-MS). Characterization of chemical compounds of *K. galanga* in Kemuning is expected to identify its particular health benefits.

MATERIALS AND METHODS

Study area

Kemuning Village is located in Ngargoyoso Sub-district, Karanganyar District, Central Java, Indonesia (Figure 1) a tourist area for tea production centers. The tourism sector is a vital source of regional income, so efforts need to be made to continue to develop, considering its excellent potential. Warm temperatures, ample rainfall, and high humidity characterize the climate in Kemuning village. These conditions are optimal for the growth of *K. galanga*, which thrives in tropical and subtropical regions. The warm temperatures promote rapid plant growth, while the abundant rainfall ensures a steady water supply (Muryani et al. 2019).

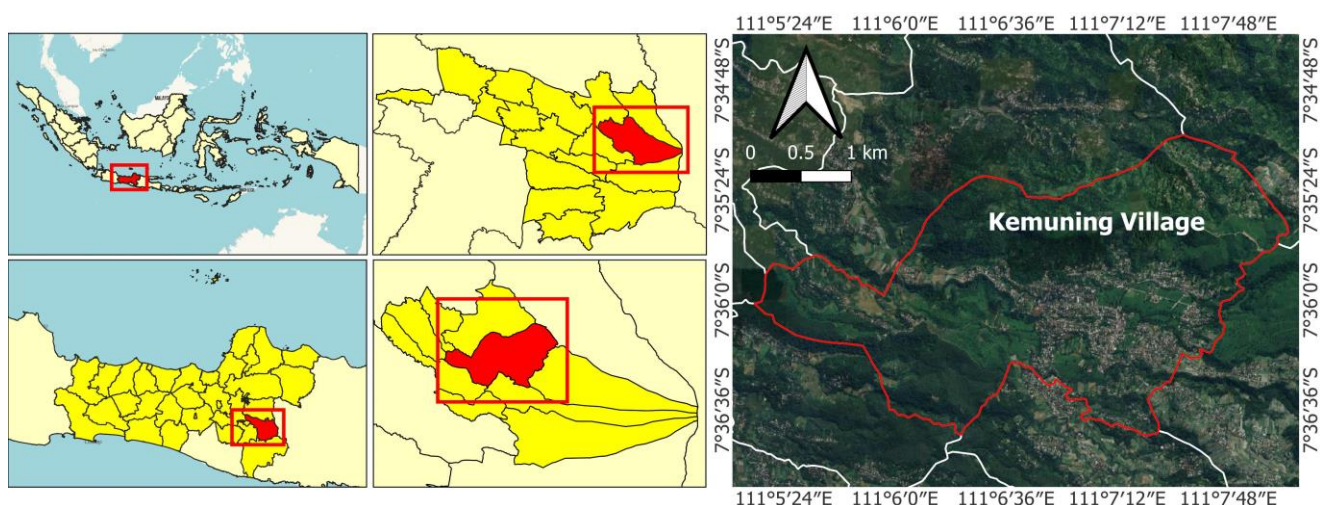


Figure 1. Location of Kemuning Village, Ngargoyoso Sub-district, Karanganyar District, Central Java, Indonesia

The soil in Kemuning village is rich in organic matter and nutrients, providing the ideal for *K. galanga* cultivation. The soil's organic content helps retain moisture and provides essential nutrients for plant growth. Additionally, the well-drained soil ensures proper aeration and prevents root rot. Water availability is another crucial factor for successful *K. galanga* cultivation. Fortunately, Kemuning village has abundant water resources from nearby rivers and streams. It ensures a consistent water supply for irrigation, essential for maintaining the herb's moisture levels throughout the year (Minarno et al. 2022). In addition to these favorable environmental factors, Kemuning Village also benefits from a strong tradition of herbal cultivation. The villagers deeply understand the growing requirements of *K. galanga* and possess the expertise to cultivate it effectively. This traditional knowledge ensures that the herb is grown sustainably and in an environmentally friendly way.

Procedures

Sample preparation

Sample preparation was conducted to eliminate factors interfering with the sample analysis process. Ten milliliters of essential *K. galanga* oil were obtained by distillation in the Kemuning, Ngargoyoso, Karanganyar district. The essential oil was filtered using 0.45 μ m Whatman filter paper, while the mobile phase was filtered using 0.2 Whatman filter paper. Filtration was followed by degassing to remove gas and avoid bubbles during sample analysis.

Sample derivatization

Derivatization before separation by gas chromatography is carried out to increase the thermal stability of a compound. Sample derivatization is a crucial step in processing *K. galanga* essential oil to enhance its compatibility with analytical instruments and improve the detection of its

constituents. This process involves chemically modifying the components of the essential oil to make them more amenable to analysis. The derivatization technique for *K. galanga* essential oil involves silylation, where a silylating agent, such as Trimethylsilyl Chloride (TMSCl) or N-methyl-N-trimethylsilyl Trifluoroacetamide (MSTFA), is added to the oil. This reaction replaces the hydroxyl (-OH) groups of certain compounds in the oil with trimethylsilyl (-TMS) groups. The TMS groups make the compounds more volatile and less polar, enhancing their separation and detection by Gas Chromatography-Mass Spectrometry (GC-MS) (Nurhaslina et al. 2022).

GC-MS analysis

The chemical compounds of *K. galanga* are analyzed using the Gas Chromatography Mass Spectrophotometry (GCMS) analysis. A total of 0.5 mL of the crude extract was put into a microtube containing 1.5 mL of the appropriate solvent, then vortexed for 1 minute and centrifuged for 3 minutes at 9000 rpm. The supernatant was subjected to GC-MS analysis with an injection volume of 5 μ L with an injection port temperature of 250°C, ion source temperature of 230°C, interface temperature of 280°C, and quadrupole temperature of 140°C. Helium gas was used as a carrier with a constant 1.2 mL/min flow rate. Every peak in the chromatogram was identified by comparing the retention time and Mass spectra in the WILLEY229.LIB and NIST62.LIB databases.

RESULTS AND DISCUSSION

The chromatogram of chemical compounds of *K. galanga* essential oil from Kemuning, Ngargoyoso, by GCMS analysis, was presented in Figure 2.

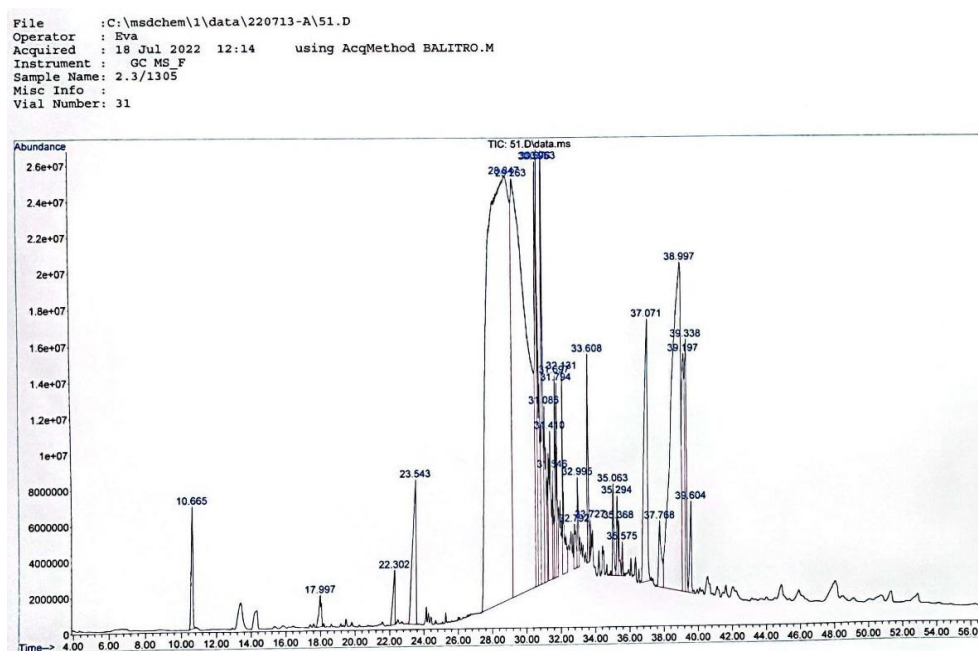


Figure 2. GCMS chromatogram of the essential oil of *Kaempferia galanga* rhizome

A previous study by Soleh and Megantara (2019) showed that the chemical compounds in *K. galanga* essential oil are ethyl cinnamate (65.98%), ethyl p-methoxycinnamate (23.65%), (+)-3-Carene (3.42%), Beta-Pinene (2.09%), camphene (1.67%), hexadecane (1.61%), Alpha-Pinene (0.71%), myrcene (0.50%), and 1-limonene (0.37).

The chromatogram of *K. galanga* essential oil presented 31 peaks that are composed of secondary metabolite compounds from the group of hydrocarbons, monoterpenoids, sesquiterpenoids, phenylpropanoids, aliphatic acid esters, and others. There are several main components of *K. galanga* essential oil, namely Pentadecane (36.64%), Cyperene (1.16%), Alpha-gurjunene (1.04%), Heptadecane (1.24%), 8-Heptadecane (1.68%), gamma-Murolene (1.55%), (2,2)-3,6-Nonadienal (2.41%), Ethyl (2E)-3-Phenyl-2-Propenoate (16.02%), Ethyl P-methoxycinnamate (6.36%), and Ethyl P-methoxycinnamate (25.54%). The results showed that the main compounds of *K. galanga* from Kemuning are dominated by pentadecane, Ethyl P-methoxycinnamate, and Ethyl (2E)-3-Phenyl-2-Propenoate, which influence the characteristics of its biological activities. The remaining 6.36% are minor compounds consisting of Eucalyptol, P-Mentha-1,5-dien-8-ol, Endo-borneol, 2-Carene-4-ol, P-Cymen-8-ol, Eucarvone, Benzaldehyde, 4-methoxy-, 3-carene-2,5-dione, Anisaldehyde dimethyl acetal, Tetradecane, (-)- α -gurjunene, γ -cadinene, Germacrene B, Humulene 6,7-epoxide, Dibutyl phthalate, Ethyl 3-(3,4-methoxyphenyl)acrylate, Hexadecanoic acid, ethyl ester, and Linoleic acid ethyl ester. Minor compounds also play an important role in the biological activity of *K. galanga*, although in low concentration.

Benefits and bioactivity

Ethnobotanically, *K. galanga* has been used as a traditional medicine to relieve coughs, maintain stamina, and remedy bruises. It can be applied orally and externally by pounding and mixing it with black sticky rice and then applying it to the bruised area (Nuraeni et al. 2022). Following are the compounds in *K. galanga* essential oil and their bioactivity:

Pentadecane (36.64%),

Pentadecane is a hydrocarbon compound belonging to the family of alkanes. It is characterized by its straight-chain structure, consisting of 15 carbon atoms. In botanical terms, it is categorized as a Volatile Organic Compound (VOC) due to its ability to evaporate at ambient temperatures. A study conducted by (Chen et al. 2019) reported that pentadecane is one of the major constituents responsible for the characteristic scent of the plant. Pentadecane contributes significantly to the strong aromatic scent that distinguishes it from other plant species. Its ability to volatilize easily and interact with the atmosphere is vital in dispersing the aromatic compounds, resulting in the ginger's distinct fragrance. Chuah et al. (2018) reported that pentadecane compounds can synthesize collagen and antimicrobial and anti-inflammatory activity. Okechukwu (2020) demonstrated that the anti-inflammatory effects are directly related to pentadecane content. The compound inhibits the production

of pro-inflammatory mediators, which could be beneficial in treating various inflammatory conditions.

Ethyl P-methoxycinnamate (25.54%) and Ethyl P-methoxycinnamate (6.36%)

The Ethyl P-Methoxycinnamate compound (6.36%) was detected at a retention time of 54.218. In comparison, ethyl p-methoxycinnamate (25.53%) was detected at a retention time of 58.378. Ethyl P-Methoxycinnamate belongs to the carboxylic acid group. Many homologous compounds, such as carboxylic acids, have very similar MS spectra, making it possible to be identified as the same compound at different peaks. The appearance of two peaks with the same compound was possibly influenced by the degree of derivatization of a mixture, column conditions, sample quantity, or injection method.

Ethyl P-Methoxycinnamate (EPMC) is natural compound in *K. galanga*. In the *K. galanga* plant, EPMC plays a crucial role in the plant's defense against various environmental stresses and pathogens. It also contributes to the plant's medicinal properties. EPMC is known for its anti-inflammatory, anti-angiogenic, and anticancer activities. It inhibited the growth of rat granuloma tissue, interleukin, and tumor necrosis factors in vivo and in vitro. However, its effect on nitric oxide production in macrophages was comparatively modest. It also suppresses pro-inflammatory cytokines and angiogenesis, hindering endothelial cells' primary function and highlighting its remarkable anti-inflammatory potential. Due to its anti-inflammatory and anti-angiogenic properties, ethyl-p-methoxycinnamate is a promising therapeutic candidate for treating inflammation- and angiogenesis-associated diseases (Umar et al. 2014). EPMC suppresses the production of pro-inflammatory cytokines and mediators, such as tumor necrosis factor- α (TNF- α) and interleukin-1 β (IL-1 β), which are involved in the development of chronic inflammatory diseases. EPMC inhibits the formation of new blood vessels, a process known as angiogenesis, which is essential for tumor growth and metastasis. EPMC's anti-angiogenic activity is due to its ability to suppress the proliferation and migration of endothelial cells, the building blocks of blood vessels (Begum et al. 2023). Ethyl P-Methoxycinnamate (EPMC) is an important bioactive compound in *K. galanga* with a wide range of pharmacological activities, including anti-inflammatory, anti-angiogenic, and anticancer properties. Its presence in the plant contributes to its therapeutic potential and supports its traditional medicinal uses. Moreover, Kumar (2020) reported that the high content of ethyl p-methoxycinnamate in *K. galanga* essential oil allows it to be used as a skin whitening agent and has a hypopigmentation effect.

Ethyl (2E)-3-Phenyl-2-Propenoate (16.02%),

Phenyl propenoic acid, or cinnamic acid, is an organic compound classified as phenolic acid. Its chemical structure comprises a phenyl ring attached to a functional group of propenoic acid. Phenyl propenoic acid is naturally contained in various plants, including *K. galanga*, and as an intermediate in the biosynthetic pathway of other phenolic compounds. 3-phenyl-2-propenoic acid, also called cinnamic acid, is

non-toxic with various biological activities, one of which is antibacterial (Demir et al. 2023). Cinnamic acid has antimicrobial activity, whereas cinnamic acid epoxide shows some activity against *E. coli* and *C. albicans* (Jacob et al. 2020). Based on these activities, cinnamic acid is very prospective to be developed as an antibacterial.

Phenyl propenoic acid exhibits numerous phytochemical and medicinal properties. Demir et al. (2023) showed that phenyl propenoic acid has the potential as an antioxidant, anti-inflammatory, and antimicrobial agent. Phenyl propenoic acid has also demonstrated anticancer and hepatoprotective activities (Wang et al. 2023) and plays a crucial role in the aroma of aromatic ginger (Xue et al. 2022). As a precursor to various volatile compounds, it contributes to the distinct and pleasant fragrance that characterizes this species. In addition to its aromatic function, phenyl propenoic acid also possesses valuable phytochemical and medicinal properties, enhancing aromatic ginger's overall desirability and potential health benefits. Understanding the function of phenyl propenoic acid in aromatic ginger provides critical insights into this plant species' complex chemistry and bioactivity. Its medicinal properties further contribute to the overall health benefits associated with the consumption of *K. galanga* rhizomes.

(*Z,Z*)-3,6-Nonadienal (2.41%)

3,6-Nonadienal contributes to the aromatic profile of ginger. A mixture of woody, grassy, and citrus-like scents characterize its strong and pleasant odor. This aromatic compound helps create the distinctive fragrance that is associated with ginger. Its use in cooking may add a pleasant and inviting aroma to dishes, making them more appealing and exciting. It is a member of the group of organic substances called medium-chain aldehydes because it has six to twelve carbon atoms in its chain. (3*Z*,6*Z*)-3,6-Nonadienal is a soapy substance with a fat taste. In addition, (3*Z*,6*Z*)-3,6-Nonadienal is a primary and essential metabolite that directly affects development, reproduction, and growth. It has been identified in several different foods, including rye (*Secale cereale* L.), cape gooseberry (*Physalis peruviana* L.), wax apple (*Eugenia javanica* Lam.), dill (*Anethum graveolens* L.), and Japanese walnut (*Juglans ailantifolia* Carrière), although its quantity has not been determined. Therefore, (3*Z*,6*Z*)-3,6-nonadienal may be a useful biomarker for this particular diet.

3,6-Nonadienal also possesses antimicrobial properties against various pathogens, including bacteria and fungi. Therefore, aromatic ginger is an effective ingredient in combating microorganisms, ensuring food safety and longevity. Incorporating ginger in food preparation enhances the taste and contributes to its preservation. In addition to its flavorsome and preservative properties, it also possesses anti-inflammatory and antioxidant properties, which may positively affect human health. These properties make aromatic ginger a potential natural remedy for various ailments, including digestive issues, muscle pain, and respiratory problems (Hou et al. 2020).

Heptadecane (1.24%), and 8-Heptadecane (1.68%),

Heptadecane, also known as $\text{CH}_3\text{-(CH}_2\text{)}_{15}\text{-CH}_3$, belongs to the class of organic compounds known as alkanes. It is a branched or unbranched acyclic hydrocarbon with the general formula $\text{C}_n\text{H}_{2n+2}$, consisting entirely of saturated hydrogen and carbon atoms. Heptadecane is a highly hydrophobic molecule, practically insoluble in water, and relatively neutral. Thus, Heptadecane is considered a hydrocarbon lipid molecule. Heptadecane, an alkane hydrocarbon with the chemical formula $\text{C}_{17}\text{H}_{36}$, is an organic compound. Among its theoretically possible structural isomers, the densest and branched isomer is tetra-tert-butylmethane, but its existence is believed to be impossible due to steric hindrance. Heptadecane may refer to 24,894 possible structural isomers or a mixture. Heptadecane is an alkane-tasting compound and has been detected, but not quantified, in several different foods, such as lemon balm, coconut, orange peppers, allspice, and pepper (*C. annuum*). Heptadecane could be a potential biomarker for these types of food sources. In IUPAC nomenclature, the name of this compound is simply Heptadecane because the other isomer is viewed and named as an alkane substituted version of a smaller alkane. The unbranched isomer, normal or n-heptadecane, represents the chemical formula $\text{CH}_3(\text{CH}_2)_{15}\text{CH}_3$. It is believed to be the smallest alkane, which is theoretically impossible. Research conducted by (Kim et al. 2000) stated that Heptadecane functions as an antioxidant compound that can block fatty acid synthesis and improve several diseases associated with oxidative stress.

Gamma-Muurolene (1.55%)

Gamma-Muurolene, also known as γ -muurolene or delta-muurolene, belongs to a class of organic compounds known as sesquiterpenoids. It is a terpene with three isoprene units in a row. Perera et al. (2017) found that essential oil from *Hyptis monicola* Mart. ex Benth., a wild plant species from Brazil, contains alpha-muurolene (6.4%), which has the potential as an antibacterial and antifungal with a percentage of 6.4%. Its chemical formula is $\text{C}_{15}\text{H}_{24}$, with a molecular weight of 204.35 g/mol (Hashiguchi et al. 2022). The compound possesses a unique structure consisting of three isoprene units connected by carbon-carbon double bonds, resulting in a 15-carbon backbone.

Gamma-muurolene contributes significantly to the distinct aroma of aromatic ginger. It exhibits a warm and spicy scent with woody undertones, crucial for its incorporation in perfumes, cosmetics, and culinary preparations (Song et al. 2021). Gamma-muurolene's aromatic profile adds depth and complexity to the overall fragrance of aromatic ginger, enhancing its appeal in various applications. Research has demonstrated that gamma-muurolene exhibits inhibitory effects against different microorganisms, including bacteria and fungi (Tuan et al. 2019). Its antimicrobial activity may provide a natural alternative for combating pathogens and preventing microbial infections. Gamma-muurolene displays anti-inflammatory properties by suppressing the production of pro-inflammatory molecules such as nitric oxide (Munda et al. 2018). This ability suggests its potential for managing inflammatory conditions and related diseases. The antioxidant activity of gamma-muurolene helps to neutralize harmful

free radicals in the body, thereby reducing oxidative stress and protecting cells from damage (Queiroz et al. 2014). This antioxidative property holds promise in various health applications, including anti-aging and disease prevention. Preliminary studies have indicated that gamma-murolene possesses anticancer properties, exhibiting cytotoxic effects against certain cancer cell lines. It can inhibit tumor growth and induce apoptosis (Catalani et al. 2017).

Gamma-murolene, a sesquiterpene hydrocarbon found abundantly in aromatic ginger, contributes significantly to this plant's distinctive aroma and potential therapeutic benefits. Its versatile nature, including antimicrobial, anti-inflammatory, antioxidant, and anticancer activities, exhibits immense potential for various applications in medicine, natural remedies, and healthcare products. Further research is required to explore the full range of gamma-murolene's functions and validate its efficacy in different therapeutic contexts.

Cyperene (1.16%),

Alpha-cyperene, also known as α -cyperene or 4-isopatchoulene, belongs to a class of organic compounds known as sesquiterpenoids. It is a terpene with three isoprene units in a row. Cyperene is a sesquiterpene hydrocarbon, a class of organic compounds known for their potent biological activities. It is obtained in the rhizomes of aromatic ginger, the underground stem responsible for the plant's growth and nutrient storage. Cyperene is known to possess multiple functions that contribute to the medicinal value of aromatic ginger.

Cyperene in aromatic ginger possesses anti-inflammatory properties (Suárez et al. 2006). A wealth of research supports the strong inhibitory effects of Cyperene on inflammatory markers and enzymes in the body. Inflammation is a natural defense mechanism triggered by injury or infection, but chronic inflammation can lead to various diseases, such as arthritis, cancer, and cardiovascular disorders. Cyperene helps to suppress the production of pro-inflammatory cytokines, reducing the overall inflammatory response in the body. Cyperene's well-established antioxidant activity highlights its significance in addressing oxidative stress. Oxidative stress occurs when the body's antioxidant defenses are overwhelmed by the production of harmful Reactive Oxygen Species (ROS), potentially leading to cellular damage and the development of chronic diseases like cancer, diabetes, and neurodegenerative disorders. Cyperene scavenges these harmful ROS, reducing oxidative stress and protecting cells against damage. Cyperene also exhibits antimicrobial properties against many bacteria and fungi, contributing to the traditional use of aromatic ginger in treating various infections. This antimicrobial activity is attributed to its ability to disrupt the cell membrane of microorganisms, thereby inhibiting their growth and proliferation. Cyperene's antimicrobial function makes it a valuable natural remedy for combating infections and maintaining overall health (Zhang et al. 2020).

Alpha-gurjunene (1.04%),

Alpha-Gurjunene or (-)-Alpha-Gurjunene belongs to a class of organic compounds known as 5,10-

cycloaromadendrane sesquiterpenoids. An aromadendrane sesquiterpenoid arises from the C5-C10 cyclization of the aromadendrane framework. It is formally classified as a polycyclic hydrocarbon, although biochemically, it is a sesquiterpenoid because it is synthesized via isoprene units. Sesquiterpenes are terpenes containing 15 carbon atoms and consisting of three isoprene units. Sesquiterpene biosynthesis occurs primarily via the cytosol's Mevalonic Acid (MVA) pathway. However, recent studies have uncovered evidence of crosstalk between the MEP and the isoprenoid pathways in the cytosol. Farnesyl Diphosphate (FPP), a crucial intermediate in cyclic sesquiterpene biosynthesis, undergoes a series of cyclization reactions to generate diverse cyclic arrangements. Alpha-gurjunene is a neutral hydrophobic molecule that is insoluble in water. It is a clear, colorless liquid with a woody, balsamic odor; used as a perfume agent. Alpha-gurjunene can be obtained in herbs, essential oils, and foods, including allspice, bay leaves, carrot seeds, eucalyptus, guava, parsley, black paper, sage, and tea tree oil.

Warsinah et al. (2011) showed that the stem bark methanol extract of *S. koetjape* containing α -gurjunene inhibits the growth of *C. albicans*. The essential oil of *K. galanga* contained 43.02% alpha-gurjunene. Therefore, the essential oil extract of *K. galanga*, besides having a distinctive and fragrant aroma, can also be used as an antifungal.

Minor compounds (6.36%)

The minor compounds in *K. galanga* essential oil have important roles and benefits, such as anti-inflammatory, antioxidant, antimicrobial, anti-acne, anticancer, and other substantial biological activities. Most of the minor compounds detected were the terpenoid group and its modifications. Eucalyptol is a terpenoid compound with anti-inflammatory, antioxidant, physicochemical characteristics (Seol and Kim 2016). P-mentha-1,5-dien-8-ol is a biocontrol agent, especially as an attractant or repellent against several insect species (Hick et al. 1999). The p-cymen-8-ol compound has an antimicrobial effect (Griffin et al. 1999). Endo-borneol has a neuroprotective effect, which is important for preventing and treating nerve injury and can accelerate the regeneration of brain nerve tissue. In addition, Endo-borneol has anti-inflammatory, antipyretic, analgesic, antitumor, antibacterial, and permeation-promoting effects (Chen et al. 2019). Eucarvone is a bicyclic monoterpene ketone with antibacterial, antifungal, antiparasitic, anticancer, antioxidant, anti-inflammatory, and anti-neuraminidase (Bakrim et al. 2022). Previously, it was explained that the ethyl p-methoxycinnamate content (25.53%), the main compound in *K. galanga*, has properties as a skin whitening agent and hypopigmentation effect. The potential of *K. galanga* as a cosmetic is due to the presence of linoleic acid ethyl ester, which has the potential as an anti-melanogenesis, antibacterial, anti-inflammatory, and anti-acne agent (Ko and Cho 2018).

Side effect of excessive *K. galanga* consumption

It has been discussed previously that *K. galanga* contains some beneficial bioactive substances. However, consuming *K. galanga* in inappropriate conditions and doses

can disrupt physiological functions and cause undesirable effects. These negative impacts include causing stomach irritation and allergic reactions in specific individuals, triggering complications, and burdening kidney function due to the diuretic effect and residue produced. Consuming excessive amounts of *K. galanga* with anti-inflammatory drugs can trigger severe bleeding. According to Sisangtragul and Sripanidkulchai (2011), limiting the intake of *K. galanga* when consuming certain drugs also aims to reduce the risk of toxicity and carcinogenesis from drugs and components which CYP1A1, CYP2B, and CYP2E1 metabolize. Therefore, people who are taking anti-inflammatory drugs are advised to limit their consumption of *K. galanga* or consult a doctor first.

In conclusion and for future directions, *K. Galanga* is one of Indonesia's most important traditional medicines. GC-MS analysis showed several main components of *K. galanga* essential oil, i.e., Pentadecane, Cyperene, Alpha-gurjunene, Heptadecane, 8-heptadecane, gamma-Murolene, (2,2)-3,6-Nonadienal, Ethyl (2E), 3-Phenyl-2-Propenoate, Ethyl P-Methoxycinnamate, and Ethyl P-Methoxycinnamate. The three most common bioactive compounds in essential oil extract are pentadecane, ethyl p-methoxycinnamate, and ethyl (2E)-3-phenyl-2-propenoate, contributing to its particular health benefits. The chemical compounds in *K. galanga* essential oil from Kemuning may have many pharmacological properties such as antifungal, anticancer, anti-angiogenic, antipyretic, antibacterial, anti-acne, anti-inflammatory, antioxidant, anti-neuraminidase, antiparasitic, and anti-melanogenesis. Ethnobotanically, the phytochemical compounds of *K. galanga* regulate multiple pathways related to improving health and their wide application in the pharmaceutical industries. Advances in analytical techniques have provided valuable insights into the biological functions of *K. galanga*. It is traditionally used as a potential herbal medicine; however, its potential should be explored further through rigorous biological assays and animal models. Clinical trials are needed for scientific proof and to determine the safety of its use.

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