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Kaempferia galanga Linn: A Systematic Review of Phytochemistry, Extraction Technique, and Pharmacological Activities

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Kaempferia galanga Linn is an endangered medicinal plant that contains high value essentials. This plant belongs to the *Zingiberaceae* family and is used in pharmaceuticals and cosmetics, as well as food. This paper aims to review the research progress on *K. galanga Linn,* particularly on the phytochemistry and extraction process of this plant, including a new perspective on its pharmacological activities. Data and information on this aromatic ginger were collected and summarised from various resources, mainly from Science Direct and Web of Science. The main bioactive compounds extracted from its rhizome were ethyl cinnamate, ethyl p-methoxycinnamate, kaempferol, camphene, linoleoyl, borneol, and 1,8-cineole. These bioactive compounds have numerous nutraceutical properties, such as antioxidant, anti-inflammatory, anti-microbial, analgesic, anti-tuberculosis, anticancer, wound healing, and mosquito repellent. Furthermore, chemical characterisation, in vitro analysis, and in vivo biological studies have confirmed the traditional uses of this plant.

Keywords: *Kaempferia galanga*; *Zingiberaceae*; Rhizome; Ethyl cinnamate; Ethyl p-methoxycinnamate

I. INTRODUCTION

For thousands of years, plants have been utilised as medicine by humans and play a vital role in the primary healthcare of rural places worldwide (Panyadee *et al.*, 2019). Medicinal plants are the primary source of novel chemical compounds with therapeutic promise. Most people in developing nations rely almost entirely on traditional medical practices as their primary healthcare practice and as the principal source of pharmacological therapy in traditional medicine (Ridtitid *et al.*, 2008). In addition, herbs and spices used as seasonings in culinary applications are recognised as having the ability to improve the sensory characteristics of food since ancient times. Herbs are related to the leaves of a plant in cooking, whereas spices refer to any other parts of the plant (Yuliana *et al.*, 2011). Eating raw plants is also considered a traditional healthy diet. This diet is high in antioxidants, including phytochemicals, vitamins, and enzymes, as well as other minerals and fibre that are good for human health. Consuming raw plants is an excellent step to help prevent degenerative diseases (e.g., cancer, diabetes, hypertension, and cardiovascular disease), delay the signs of ageing, and improve physical fitness. Among the phytochemicals found in plants, phenolic compounds are the main bioactive compound contributing to the higher value of antioxidant activity (Sulaiman *et al.,* 2011). Moreover, natural phytochemicals are used in traditional Ayurveda as an alternative strategy to effectively treat ailments. Therefore, the demand for herbal medicines has grown tremendously due to safer choices, availability, and economic benefits (Amalraj *et al.*, 2019).

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Kaempferia galanga Linn (K. galanga Linn) belongs to the *Zingiberaceae* family, which consists of roughly 60 species (Alsalhi *et al.*, 2020) found in tropical countries, such as India, China, Indonesia, Cambodia, Malaysia, Myanmar, and Thailand (Swapana *et al.*, 2018). *K. galanga Linn* is one of the most important species in the *Zingiberaceae* family on an industrial scale. It is also known as aromatic ginger (Alsalhi *et. al.,* 2020; Yao *et al.,* 2018) and sand ginger (Yao *et al.*, 2018), which is a popular condiment in Asian cuisines, but rarely known in Western countries. The *Zingiberaceae* family consists of a significant variety of medicinal plants that are well-known for their ethnomedicine applications (Tushar *et al.*, 2010). It is commonly known as "cekur" in Malaysia, "kencur" in Indonesia, "shan-nai" by the Chinese (Othman *et al.*, 2006), and "proh hom" in Thailand (Ridtitid *et al.*, 2008).

The *Kaempferia* genus has approximately 60 economically valuable species due to their widespread ethnomedicinal uses. Labrooy *et al.* (2018) have identified the ethnomedicinal importance of *Kaempferia* species based on morphological traits and suitable DNA regions. Based on their findings, morphological and molecular data have taxonomic congruence. Leaf parameters, rhizome colours, and plant habit are the most distinguishing morphological features in recognising *Kaempferia* species when flower components are unavailable. Nonetheless, DNA barcodes are preferred since they can be used to identify this herbal plant, especially in determining and preserving its quality for herbal business purposes (Mohammed Abubakar *et al.*, 2017). Figure 1 shows a photo of the *Kaempferia galanga Linn*.

Based on a literature review conducted in this study, notable reviews already exist in related areas of research. Munda *et al.* (2018) reviewed the chemical composition and biological activities of the essential oil of *K. galanga Linn*. They revealed that the major chemical constituents in the essential oil of *K. galanga Linn* are ethyl trans-p-methoxycinnamate, ethyl cinnamate, and pentadecane.

Figure 1. *Kaempferia galanga Linn*

However, to the best of our knowledge, no systematic literature review (SLR) on *Kaempferia galanga Linn* has been published yet. Therefore, this systematic literature review aimed to summarise any information found related to *K. galanga Linn.*

II. MATERIALS AND METHODS

A. Methods

This systematic literature review (SLR) aimed to search and synthesise findings reported by previous studies or research. This process was transparent and used repeatable techniques during each step according to the five steps reported by Ismail *et al.* (2021). The SLR steps are shown in Figure 2, which consist of defining the research questions, explaining the search strategy, determining the inclusion and exclusion criteria, assessing quality, gathering data, and performing a descriptive analysis (Khallaf & Khallaf, 2021).

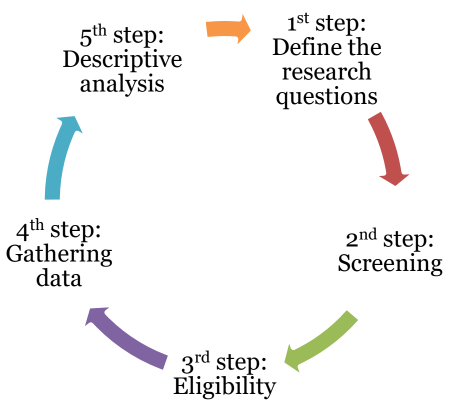


Figure 2. Flowchart of a systematic literature review

B. Research Questions

The first step was to address the following research questions (RQs) using the SLR technique. This review paper aimed to answer five RQs, as follows:

RQ1. What are the important research profiles previously discussed regarding *Kaempferia galanga Linn*?

RQ2. What are the research topics related to pressing issues addressed in the literature on phytochemical substances in *Kaempferia galanga Linn*?

RQ3. Based on previous research, what are the extraction procedures used to extract essential oil from *Kaempferia galanga Linn*?

RQ4. What are the research gaps and limitations identified in previous studies?

RQ5. How can previous research on the phytochemical compounds in *Kaempferia galanga Linn* extract help future research?

C. Screening

The second step in the SLR was to use keywords and search strings consisting of "*Kaempferia galanga*" (accessed on July 20, 2021), which yielded 290 articles from Science Direct, 1,210 articles from the Scopus database, and 189 articles from Web of Science (WoS). This strategy aimed to find the intended concept and case studies. However, several articles have to be excluded from the inclusion criteria. These included systematic review articles, review articles, meta-analyses articles, meta-synthesis articles, book series, books, chapters in a book, conference proceedings, and non-English articles. Then, the remaining articles were uploaded to Mendeley for data crunch. Data crunching entailed deleting duplicate articles and updating the details of each paper.

D. Eligibility

The third step involves an eligibility process, as shown in Table 1. This process was performed to define the eligibility, inclusion, and exclusion criteria of relevant articles for inclusion in the systematic review. The inclusion and eligibility criteria are central features of the SLR design. The criteria of article titles, abstract, and complete text were also used during the eligibility process to determine which articles to be included in this review.

Table 1. Inclusion and exclusion criteria

Criterion	**Eligibility**	**Exclusion**
Literature type	Indexed Journal (research articles)	Non-indexed journals, systematic review journals, chapters in a book, conference proceeding
Language	English	Non-English

This review has excluded several articles that did not meet the objectives, have no empirical data, did not focus on *K. galanga Linn*, and were not in the Q1 and Q2 of quality journal impact score.

E. Gathering Data

The fourth step was to collect data once the eligibility process was completed. Each article was exported to the xml format from the Mendeley platform after it has been screened and checked for eligibility. This procedure ensured that all files could be imported into the Atlas.ti 9 programme. This advanced software allows users to organise, rearrange, and manage their files creatively and logically. Atlas.ti 9 with a student licence (L-EC5-619) was utilised for this review work.

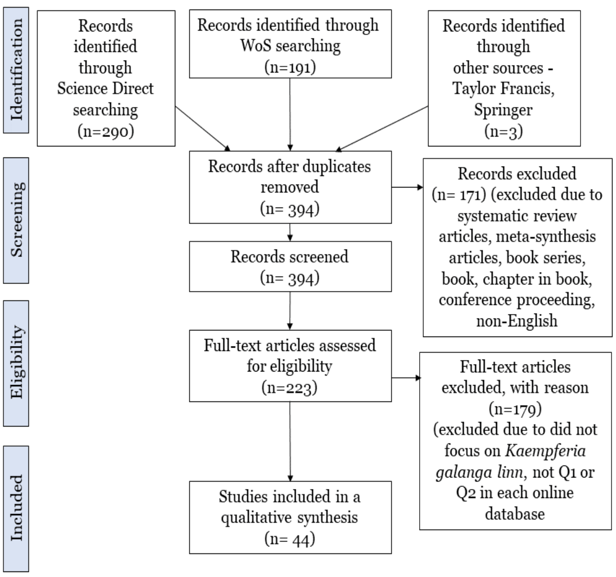


Figure 3. Flowchart of the screening process

F. Descriptive Analysis

The final step was data abstraction and analysis. The remaining articles were examined, reviewed, and analysed; subsequently, 223 articles (studies) were treated in-depth in this work. The reviews were based on specific studies that corresponded to the research questions and objectives of this current study. The outcomes of this step, as indicated in Figure 3, are 44 articles. This SLR used Atlas.ti 9 to identify critical information and to compare related ideas among these articles.

III. RESULTS AND DISCUSSION

A. The Research Profile of Kaempferia galanga Linn

Most people continue to rely on traditional materials (medicinal plants and other materials) as part of their daily healthcare routine. It is also a fact that one-quarter of all medical prescriptions are for formulations based on substances derived from plants, or plant-derived synthetic equivalents (Sahoo *et al.*, 2010). The World Health Organization (WHO) estimated that 80% of the world population, especially in developing countries, rely on plant-derived medicines for healthcare (Gurib-Fakim, 2006). *K. galanga Linn* is one of the herbs that has been recognised and used for centuries.

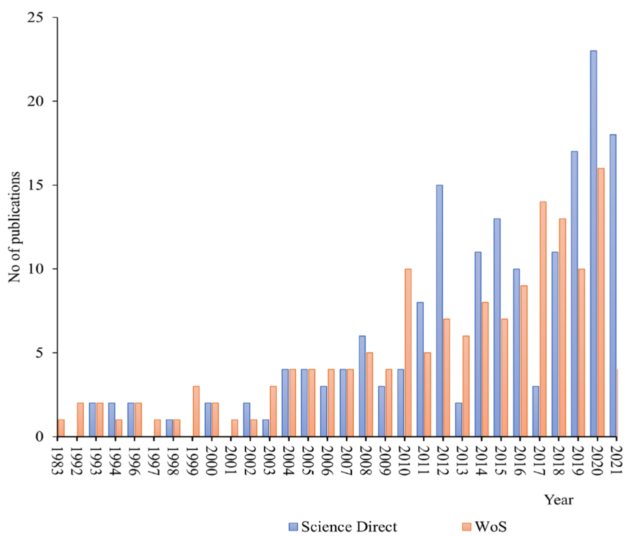


Figure 4. The number of referred papers in the digital library of Science Direct and WoS

The research profile of previous studies showed that literature on the extraction of phytochemical components of *K. galanga Linn* are relatively in demand, as the number of publications has increased tremendously since 2012 for two online databases. Figure 4 shows the number of referred articles based on Science Direct and Web of Science (WoS) digital databases from 1983 to July 2021.

Table 2 shows that the Journal of Ethnopharmacology has published the most papers related to *K. galanga* out of 44 articles reviewed in this study. These results showed that this plant has a high therapeutic value, and studies are ongoing and receiving attention from various sources, especially in the pharmaceutical field of study. The second journal to receive similar attention for this plant was the Industrial Crops and Products.

Table 2. Articles reviewed based on the title of journals, journal impact quartile, and number of published articles in Science Direct database

Title of Journal	Journal Impact Quartile	No. of published articles
Journal of Traditional and Complementary Medicine	Q1	1
Chinese Journal of Natural Medicines	Q1	1
Current Plant Biology	Q2	1
Fitoterapia	Q2	5
Food and Chemical Toxicology	Q1	1
Food Chemistry	Q1	2
Industrial Crops and Products	Q1	7
Journal of Ethnopharmacology	Q2	11
Journal of Food Composition and Analysis	Q1	1
Journal of Herbal Medicine	Q2	2
Journal of Integrative Medicine	Q1	1
Journal of King Saud University – Science	Q1	2
LWT - Food Science and Technology	Q1	1
Neuroscience Letters	Q2	1
Phytochemistry	Q1	1
Phytomedicine	Q1	2
Plant Diversity	Q1	1
Separation and Purification Technology	Q1	2
Toxicology Reports	Q1	1

In conclusion, researchers who are interested in studying this plant could use this SLR as a basis for selecting journals for further studies.

Meanwhile, Figure 5 shows Indonesia, India, Thailand, China, Japan, Malaysia, and Brunei as the seven (7) countries contributing to the high number of published works on *K. galanga*. *K. galanga Linn* is a species of herb with aromatic rhizomes that have a pungent and spicy flavour. This culinary spice is always added to poultry cuisines in Southeast Asia (Ma *et al.*, 2015) to enhance the flavour, colour, and aroma. As a result, it is widely used in the culinary, seasoning, cosmetic, and pharmaceutical industries (Sulaiman *et al.,* 2008). Furthermore, due to its various biological actions, *K. galanga Linn* extract is regarded as a promising multifunctional food additive (Kumar, 2020). Consequently, most of the countries involved in this study are known for their cuisines that incorporate a wide range of herbs and natural items.

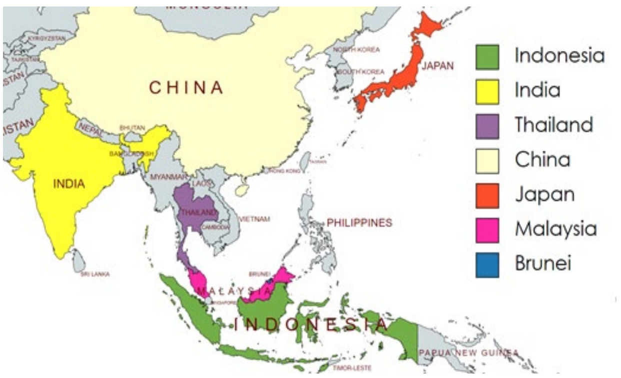
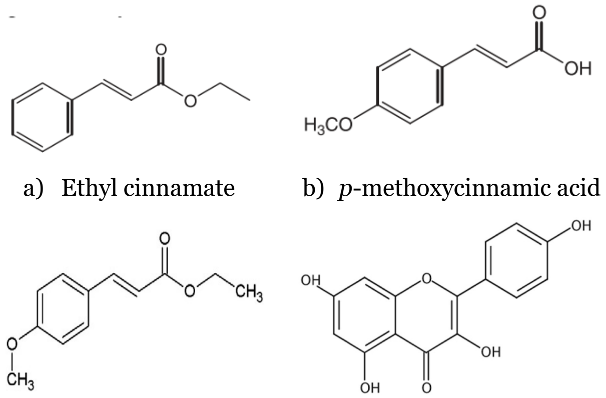


Figure 5. Countries with high numbers of published articles on *K. galanga Linn*

B. The Phytochemical Substances of Kaempferia galanga Linn

All phytochemical substances have unique physical, chemical, and biological properties that make them suitable for use in pharmaceutical products. Herbal active components differ depending on numerous circumstances, such as variety, geographic location, nutritional condition, harvest season, production technique, and even storage manner. Variations in these parameters could lead to considerable pharmacological activity variations (Liu *et al.*, 2016). A total of 58 phytochemicals have been isolated from the rhizome of *K. galanga Linn*, as listed in Table 3. The major phytochemicals found in *K. galanga Linn* essential oil were ethyl p-methoxycinnamate (32.08%), ethyl cinnamate (28.30%), pentadecane (14.85%), and globulol, or Ledol (2.35%) (Zhang *et al.*, 2020). Ma *et al.* (2015) used ultrasound-enhanced subcritical water extraction for extracting the essential oil of *K. galanga Linn*. This method produced the same results as the essential oil extracted using hydrodistillation by AlSalhi *et al.* (2020). Both papers agreed that the highest phytochemical in the essential oil of this plant is ethyl p-methoxycinnamic acid. This acid is an ester, which contributes to the pungent smell of this plant. These results showed that the extraction method does not affect the main components of the essential oil. The structural formulas of several phytochemicals found in *K. galanga Linn* are presented in Figure 6.



a) Ethyl cinnamate

b) *p*-methoxycinnamic acid

c) Ethyl *p*-methoxycinnamate

d) Kaempferol

Figure 6. The structures of several phytochemicals extracted from *K. galanga Linn*: 6(a) ethyl cinnamate (Kumar, 2020); 6(b) *p*-methoxycinnamic acid (Othman *et al.*, 2006); 6(c) ethyl p-methoxycinnamate (Lakshmanan *et al.*, 2011); and 6(d) kaempferol (Cao *et al.*, 2020)

A natural flavonoid, known as kaempferol has been demonstrated as being able to reduce pancreatic and lung cancers (Lal *et al.*, 2017). Meanwhile, Cao *et al.* (2020) reported that kaempferol acts as a protein modulator for Parkinson's disease to prevent mast cell-mediated allergic disorders by attenuating Lyn activation. Furthermore, previous experimental results have shown that kaempferol can reduce Immunoglobulin E-mediated food allergies, and enable the rehabilitative modulation of downstream signals, demonstrating its therapeutic potential for allergic disorders.

The advantages of kaempferol have also been reported by Luo *et al.* (2021). Their findings showed that kaempferol's tumour necrosis factor receptor-associated factor 6 (TRAF6) plays an essential role in inflammatory responses in diabetic nephropathy. Thus, a diet high in kaempferol has been shown to be helpful, particularly in terms of lowering the risk of chronic diseases. Furthermore, it boosts the body's defence capability by acting as an antioxidant against free radicals, which contribute to cancer development.

In a rat aortic ring assay, ethyl p-methoxycinnamate was found to have an anti-angiogenic tangible impact (Umar *et al.*, 2014). However, the essential processes of endothelial cells, including proliferation, migration, and tube formation, were also discovered to inhibit the generation of vascular endothelial growth factors, which caused the problem. Thus, ethyl p-methoxycinnamate could potentially become the starting point for developing therapeutics that target inflammation and angiogenesis (Umar *et al.*, 2014).

Table 3. Phytochemicals isolated from *K. galanga Linn*

No	**Compound**	**Molecular formula**	**Molecular weight**	**References**
1	1,8-Cineole	$C_{10}H_{18}O$	154.25	(AlSalhi *et al.*, 2020)
2	1-Hexadecene	$C_{16}H_{32}$	224.42	(AlSalhi *et al.*, 2020)
3	2-[2-(4-Nonylphenoxy) ethoxy] ethanol	$C_{19}H_{32}O_3$	308.5	(Ali *et al.*, 2018)
4	2-Propenoic acid	$C_3H_4O_2$	72.063	(Ali *et al.*, 2018)
5	3-Ethenylcyclooctene	$C_{10}H_{16}$	136.23	(Ma *et al.*, 2015)
6	3-Methyl tetradecane	$C_{15}H_{32}$	212.41	(Ma *et al.*, 2015)
7	9,12-methy octadecadienoate	$C_{19}H_{34}O_2$	294.48	(Ma *et al.*, 2015)
8	9-Octadecenoic acid methyl ester	$C_{19}H_{36}O_2$	296.39	(Ma *et al.*, 2015)
9	Borneol	$C_{10}H_{18}O$	154.25	(Ma *et al.*, 2015) (AlSalhi *et al.*, 2020)
10	Cadinene	$C_{15}H_{24}$	204	(Ma *et al.*, 2015)
11	Camphor	$C_{10}H_{16}O$	152.23	(Ma *et al.*, 2015)
12	Carophyllene oxide	$C_{15}H_{24}O$	220.35	(AlSalhi *et al.*, 2020)
13	cis-Limonene oxide	$C_{10}H_{16}O$	152.23	(AlSalhi *et al.*, 2020)
14	cis-Verbenol	$C_{10}H_{16}O$	152.23	(AlSalhi *et al.*, 2020)
15	Copaene	$C_{15}H_{24}$	204.35	(Ma *et al.*, 2015)
16	Cyclopentadecanone	$C_{15}H_{28}O$	224.38	(Ma *et al.*, 2015)
17	D-Limonene	$C_{10}H_{16}$	136.24	(Ma *et al.*, 2015)
18	Ethyl cinnamate	$C_{11}H_{12}O_2$	176.21	(Ma *et al.*, 2015)
19	Ethyl cis-p-methoxycinnamate	$C_{12}H_{14}O_3$	206.24	(Ma *et al.*, 2015)
20	Ethyl p-Methoxycinnamate	$C_{12}H_{14}O_3$	206.24	(Ma *et al.*, 2015) (AlSalhi *et al.*, 2020)
21	Eucalyptol	$C_{10}H_{18}O$	154.25	(Ma *et al.*, 2015)
22	Germacrene D	$C_{15}H_{24}$	204.35	(Ma *et al.*, 2015) (AlSalhi *et al.*, 2020)
23	Glycidyl stearate	$C_{21}H_{40}O_3$	340.5	(Ali *et al.*, 2018)
24	Heptadecane	$C_{17}H_{36}$	240.47	(Ma *et al.*, 2015)
25	Hexadecane	$C_{16}H_{34}$	226.44	(Ma *et al.*, 2015)
26	Hexadecanoic acid	$C_{16}H_{32}O_2$	256.42	(Ali *et al.*, 2018)

27	Isoborneol	$C_{10}H_{18}O$	154.25	(AlSalhi *et al.*, 2020)
28	Kaempferol	$C_{15}H_{10}O_6$	286.24	(Cao *et al.*, 2020)
29	Ledol	$C_{15}H_{26}O$	222.37	(AlSalhi *et al.*, 2020)
30	Linalool	$C_{10}H_{18}O$	154.25	(AlSalhi *et al.*, 2020)
31	Methyl oleate	$C_{19}H_{36}O_2$	296.49	(Ma *et al.*, 2015)
32	Methyl palmitate	$C_{17}H_{34}O_2$	270.00	(Ma *et al.*, 2015)
33	Myrcene	$C_{10}H_{16}$	136.24	(AlSalhi *et al.*, 2020)
34	Octadecanoic acid	$C_{18}H_{36}O_2$	284.5	(Ali *et al.*, 2018)
35	Oleic acid	$C_{18}H_{34}O_2$	282.5	(Ali *et al.*, 2018)
36	*p*-Cymene	$C_{10}H_{14}$	134.22	(AlSalhi *et al.*, 2020)
37	Pentadecane	$C_{15}H_{32}$	212.41	(Ma *et al.*, 2015)
38	Pentadecane,2,6,10-trimethyl	$C_{18}H_{38}$	254.49	(Ma *et al.*, 2015)
39	Pentadecanol	$C_{15}H_{32}O$	228.41	(AlSalhi *et al.*, 2020)
40	Phthalic acid	$C_8H_6O_4$	166.13	(Ali *et al.*, 2018)
41	*p*-Methoxycinnamic acid	$C_{10}H_{10}O_3$	178.18	(Ma *et al.*, 2015)
42	Sabinyl acetate	$C_{12}H_{18}O_2$	194.27	(AlSalhi *et al.*, 2020)
43	Sandaracopimaradiene	$C_{20}H_{32}$	272.5	(Ali *et al.*, 2018)
44	Spathulenol	$C_{15}H_{24}O$	220.35	(AlSalhi *et al.*, 2020)
45	Terpinen-4-ol	$C_{10}H_{18}O$	154.25	(AlSalhi *et al.*, 2020)
46	Tetradecane	$C_{14}H_{30}$	198.39	(Ma *et al.*, 2015)
47	Thymol	$C_{10}H_{14}O$	150.22	(AlSalhi *et al.*, 2020)
48	trans-Ethyl cinnamate	$C_{11}H_{12}O_2$	176.21	(AlSalhi *et al.*, 2020)
49	Tridecane	$C_{13}H_{28}$	184.3614	(Ma *et al.*, 2015)
50	α-Calacorene	$C_{15}H_{24}$	204.35	(Ma *et al.*, 2015)
51	α-Gurjunene	$C_{15}H_{24}$	204.35	(AlSalhi *et al.*, 2020)
52	α-Humulene	$C_{15}H_{24}$	204.35	(AlSalhi *et al.*, 2020)
53	α-Phellandrene	$C_{10}H_{16}$	136.24	(AlSalhi *et al.*, 2020)
54	α-Pinene	$C_{10}H_{16}$	136.24	(AlSalhi *et al.*, 2020)
55	α-Terpinene	$C_{10}H_{16}$	136.24	(AlSalhi *et al.*, 2020)
56	α-Terpineol	$C_{10}H_{18}O$	154.25	(AlSalhi *et al.*, 2020)
57	β-Elemene	$C_{15}H_{24}$	204.35	(AlSalhi *et al.*, 2020)
58	β-Eudesmol	$C_{15}H_{26}O$	222.37	(AlSalhi *et al.*, 2020)
59	γ-Elemene	$C_{15}H_{24}$	204.35	(AlSalhi *et al.*, 2020)
60	δ-3-Carene	$C_{10}H_{16}$	136.24	(AlSalhi *et al.*, 2020)
61	δ-Cadinene	$C_{15}H_{24}$	204.35	(AlSalhi *et al.*, 2020)

Othman *et al.* (2006) reported their pharmacological research on ethyl cinnamate and p-methoxycinnamic acid. The vasorelaxant activity of ethyl cinnamate supports the use of *K. galanga Linn* for hypertension relief. In addition, angina, asthma, and other types of generalised muscular spasms are among the numerous ailments that can be managed using the therapeutic benefits of smooth muscle relaxants.

K. galanga Linn has been used traditionally in many cultures. Figure 7 shows several uses of this plant, such as to treat gastritis (Panyadee *et al.*, 2019), fever (Srivastava *et al.*, 2021), wounds (Zhang *et al.*, 2020), as a snake antivenom (Elshamy *et al.*, 2020), diarrhoea (Yincharoen *et al.*, 2021), and vertigo (Elshamy *et al.*, 2020). In the traditional method, the mature rhizome is boiled in coconut oil or mixed with Vaseline and applied directly to the abdomen as needed

(Neamsuvan *et al.*, 2012). Meanwhile, in the research done by Tushar *et al.* (2010), the rhizome would be taken orally for treating indigestion, cold, pectoral and abdomen pain, headache, and menstrual pain. Even though this plant is often used in Ayurveda, the traditional Hindu medication system (Basak *et al.,* 2019), more studies need to be done, especially regarding dosage intake. Thus, more work needs to be done to close the gap between traditional and modern medicine.

Figure 7. Illustration of the traditional uses of *K. galanga Linn*

C. The Extraction Methods

Pre-extraction and extraction techniques for extracting bioactive components from plant materials are key phases in researching medicinal plants. Traditional techniques, such as maceration and Soxhlet extraction, are frequently used at the Small Manufacturing Enterprises (SME) level. However, modern extraction methods, such as microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), and supercritical fluid extraction (SFE), have made considerable advances in the processing of medicinal plants to boost higher yields while decreasing costs. With such a diverse range of extraction methods available, picking the appropriate extraction procedure takes considerable thought.

Various techniques have been used to extract *K. galanga Linn*, as shown in Figure 8 in yellow colour. This is because different extraction methods may result in different phytochemicals being extracted. The hydrodistillation method was utilised by Srivastava *et al.* (2019), and the results showed that ethyl p-methoxycinnamate was the main component produced. AlSalhi *et al.* (2020) discovered the same main component when extracting essential oil from *K. galanga Linn* using the same method to investigate its larvicidal activity against *Aedes vittatus* and *Anopheles maculatus*.

Another technique used in the extraction of *K. galanga Linn* is maceration, which is the most straightforward technique (Dwita *et. al.,* 2021; Tritripmongkol *et al.,* 2020). Maceration is a widespread inexpensive technique for extracting *K. galanga Linn* oil at room temperature. It involves immersing the plant's sample in a solvent inside an airtight container. However, organic wastes from this method can become a problem due to the large volume of solvents used, necessitating proper waste management. When temperature and solvent choices are not a hindrance, they can be used to improve the extraction process, minimise the volume required for extraction, and even be used in the maceration technique.

Meanwhile, Channabasavaiah Jagadish *et al.* (2016), Yao *et al.* (2018), Ridtitid *et al.* (2008), Lakshmanan *et al.* (2011), Wu *et al.* (2004), Wang *et al.* (2013), Ali *et al.* (2018), Elshamy *et al.* (2019), and Swapana *et al.* (2018) used solvent extraction in their method. Solvent extraction can be used if the phytochemicals needed cannot tolerate heat. In contrast, this procedure is highly time-consuming and thus makes the oils more costly than other methods.

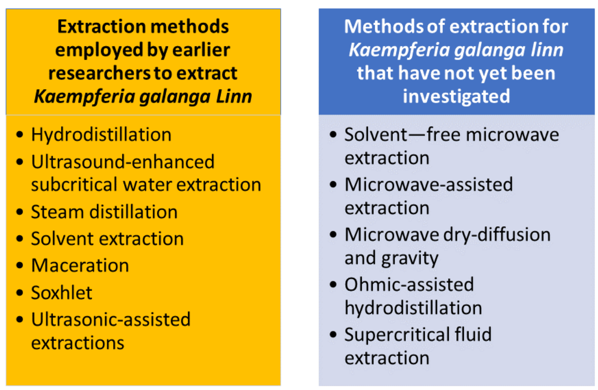


Figure 8. Different essential oil extraction methods

The extraction of *K. galanga Linn* oil using steam distillation was studied by Cao *et al.* (2020). However, steam distillation and solvent extraction have some drawbacks, such as low extraction efficiency, long extraction times, and substantial amounts of toxic solvent waste, necessitating the development of alternate procedures for essential oil extraction (Ma *et al.*, 2015). Thus, Ma *et al.* (2015) employed a novel ultrasonic-enhanced subcritical water extraction process in two phases (USWE) to extract *K. galanga Linn* essential oil. It is a hybrid of ultrasonic and water extraction methods that has resulted in a more dynamic extraction process in the second phase. This technology is quite promising because of its advantages in terms of time-saving, environmental friendliness, and high efficiency.

Another technique for extracting *K. galanga Linn* oil is the Soxhlet method (Othman *et. al.,* 2006; Umar *et al.,* 2014). However, despite its undoubted advantage of only requiring a smaller quantity of solvent compared to maceration, this method also has its limitations. One drawback is the exposure to hazardous and flammable liquid organic solvents, with potential toxic emissions during extraction. Moreover, the solvent used in the extraction process needs to be purified, which means additional costs.

Ultrasonic-assisted extraction is a modern technology that was utilised by Srivastava *et al.* (2021). The advantages of this green extraction technology are high efficiency, low energy consumption, and reduced use of organic solvents. Ultrasonic-assisted extraction is a modern extraction technology that uses the cavitation effect, mechanical vibration, and thermal effect produced by ultrasound to destroy plant cell walls, thereby, promoting the diffusion of the solvent and accelerating the dissolution of the organic compound.

Supercritical fluid extraction (SFE) is another popular which did not been explore to extract the *K. galanga Linn* yet. SFE is known due to their time-sensitive, cost-effective, and near-ambient temperature conditions. The technology has numerous commercial applications in the production of nutraceuticals, pharmaceuticals, flavours, and food, including the decaffeination of coffee or tea, the separation of fatty acids from spices, and the separation of dyes from red pepper (Pise & Thorat, 2022).

In conclusion, these extraction methods can be chosen based on the benefits in yield and selectivity, faster extraction time, essential oil composition, and environmental friendliness.

D. Research Gaps and Limitations in Research on K. galanga Linn

This investigation has found several extremely fascinating findings in a variety of areas. However, no study has been conducted to compare the results of different extraction methods for extracting *K. galanga Linn* oil. A commonly used method to extract essential oil from *K. galanga Linn* is maceration, which is considered a conventional method. Therefore, green extraction techniques, such as solvent-free microwave extraction, microwave-assisted hydrodistillation, and supercritical fluid extraction, should be taken into consideration in future studies. Since the quality of essential oils may vary depending on the location, thus, future studies are also recommended to explore more on the effects of soil and other parameters on the phytochemical compounds produced.

E. The Future Trend and Challenges of K. galanga Linn

The application of *K. galanga* in the food, pharmaceutical, and cosmeceutical industries is an exciting issue. However, researchers and industrial players should consider using green technologies to increase the safety aspect of human consumption and environmentally friendly techniques. Moreover, with the increasing health problems nowadays, essential oils from plants and natural products are gaining significant attention from the end-users.

IV. CONCLUSION

The research profiling work on *K. galanga Linn* has increased, which shows that studies on this herbal plant are significant because this herbal plant is enriched with phytochemical substances (e.g., p-methoxycinnamate) that are traditionally used to treat a variety of ailments, such as cough, cold, and fever. However, further research works are needed to close the gap between traditional and modern medicine. Among the various extraction techniques, green technologies, such as solvent-free microwave extraction, microwave-assisted extraction, and supercritical fluid extraction are promising methods to the consumers and manufacturers due to their advantages of lower costs, safer, and shorter time. In conclusion, to increase the trust and demand of consumers, extended studies and clinical trials are required to demonstrate the effectiveness of this herbal plant as a natural medicine.

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