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Pharmacological importance of *Kaempferia galanga* (Zingiberaceae): A mini review

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Abstract
Kaempferia galanga L. belonging to the family Zingiberaceae is an endangered medicinal plant with potent medicinal activities. The leaves, rhizome and root tubers of the plant possess a number of medicinal applications. The plant is economically important and is over exploited to the extent that there is always scarcity of propagating material (rhizomes) which is the consumable part too. The present review provides broad information of *Kaempferia galanga* throwing light on its current status, ethnobotany, phytochemistry and pharmacology. Extracts of *Kaempferia galanga* have anti-inflammatory, analgesic, anti-diarrheal, anti-bacterial, sedative, cytotoxic, insecticidal and anthelmintic properties which are reported here.

Keywords: *Kaempferia galanga*, zingiberaceae, phytochemistry, pharmacological activity

Introduction
Kaempferia galanga Linn., commonly known as Cekor, Ekangi, Kencur or aromatic ginger is a stem less herb in *Zingiberaceae* family. The plant is native to tropical Asia including southern China, Indochina, Thailand, Taiwan, Malaysia and India [1]. Being a source of valuable bioactive compounds, KG is famous for its medicinal as well as edible use [1]. As folk medicine, the rhizome of *K. galanga* L. is employed for antibacterial, treatment of hypertension, asthma, rheumatism, indigestion, cold and headache, relief abdominal pain and toothache [2, 3]. In Thailand, the dried rhizome has been used as cardiotonic and CNS [4], whereas an acetone extract has an effect on monoamine oxidase inhibition [5]. *K. galanga* rhizome can be used to treat wind and phlegm, restore digestive heat, and help circulate the blood [6].The powdered rhizome mixed with honey is an expectorant used to treat productive cough and pectoral affection. Besides, oil prepared from the rhizome is applied over the nasal region to relieve nasal congestion [7]. The preparation also can be used to treat wounds and applied to rheumatic region [8]. Roasted rhizomes are applied as hot poultice in rheumatism [7]. Chemical constituents isolated from *K. galanga* possess different pharmacological properties like antioxidant, antimicrobial, analgesic, anti-inflammatory, sedative, vasorelaxant, nematicidal, mosquito repellent, larvicidal, antiprotozoal and wound healing activities [9, 10]. The most vital phytoconstituent isolated from Ekangi extracts found Ethyl-cinnamate and Ethyl-p-methoxy cinnamate. Kaempferol, isolated from *K.galanga* rhizome was found effective to reduce the risk of pancreatic and lung cancer. Leaves and rhizomes of *K. galanga* are useful in treating rheumatism traditionally. *K. galanga* is one of those precious medicinal herbs that are still included in unutilized herbs in spite of the variety of useful pharmacological properties it possess. Therefore, the importance of the plant *K. galanga* as a medicinal plant is to be documented and presented to the mass of people. Keeping in view the above statement a brief and up to date review about some of the medicinal values of *K. galanga* has been made in the following study.

Botanical Classification
Kingdom: Plantae
Sub Kingdom: Phanerogamae
Division: Spermatophyta
Sub Division: Angiospermae
Class: Monocotyledonae
Order: Scitaminales
Family: Zingiberaceae
Genus: *Kaempferia*
Species: *K. galanga*

Common name
Aromatic Ginger, Resurrection lily, Lesser galangal, Sand ginger; Hindi: Chandramula, Sidhoul; Marathi: Kapurkachri; Tamil: Kacholum, Pulankilanku; Malayalam: Kachhuram, Katjulam; Kannada: Kachchura, Kachhoora; Bengali: ekangi, bhuichampa; Assamese: Chandramula; Sanskrit: Chandramoolika, corakah, karcurah, Sathi, Sati, Sugandhamula.

Botanical Description
Kaempferia galanga is a member of the Zingiberaceae family. It is a stemless herb arising from tuberous rootstocks with fibrous cylindrical roots. The rhizome has dark reddish-brown skin and the soft interior is nearly white. The leaves usually 2-3(-5), spread horizontally, dark green, broadly elliptical to

slightly flat with circular outline, measuring 8-15 cm wide. The blade is often lying flat to the soil the top surface is smooth while the bottom surface is cobweb-hairy [11].

The inflorescence is sessile, emerging from between the leaves. It is 4-12(-15)-flowered. The sepal is 2-3 cm long. The petal is white, with tube 2.5-5 cm long and lobes 1.5-3 cm long. Their lip is broadly reversed egg-shaped, divided to about halfway or more, white or pale purple with violet to purple spots at the base. Each lateral lobe is about 2-2.5 cm x 1.5-2 cm. Other abortive stamen has an imperfect anther that is oblong-reversed egg-shaped to oblong-lance-shaped, 1.5-3 cm long and white. Their fertile stamen is 10-13 mm long, with two lobes deeply connective with abruptly bent lobes [11].

Fig 1: *Kaempferia galanga*

Phytochemical Constituents

A superabundant work has been done to identify and isolate the chemical constituents from different polar and non-polar extracts of *Kaempferia galanga*. Ethyl-cinnamate and ethyl–*p*-methoxycinnamate are found to be the most vital constituents in the dichloromethane [10], hexane [12] and methanol extracts [13]. About 98.98% of essential oil constituents have been isolated and identified with only 1.11% constituents that are still unknown [13]. The most abundant essential oil constituents include propanoic acid, pentadecane, ethyl-*p*-methoxycinnamate. Other constituents include 1,8-cineol, undecanone, isopropyl cinnamate, dicyclohexyl propanedinitrile, dipentene dioxide, 9-hydroxy, 2-nonanone, 2,7- octadiene-1-yl acetate, ethyl cyclohexyl acetate, cis-11-tetradecenyl acetate, 2-heptadecanone, 4-methyl isopulegone, camphidine, trans,trans-octa-2, 4-dieny acetate, 10 undecyn-1-ol, 3,7-dimethoxycoumarin, delta- 3-carene, alpha pinene, camphene, borneol, cymene, alphaterpineol, alpha gurjunene, germacrenes, cadinenes, caryophyllenes, luteolin and apigenin [7, 10, 14, 15]. The percent concentrations of essential oil constituents are shown in Figure 2. The chemistry of important constituents of *Kaempferia galanga* is given in table.

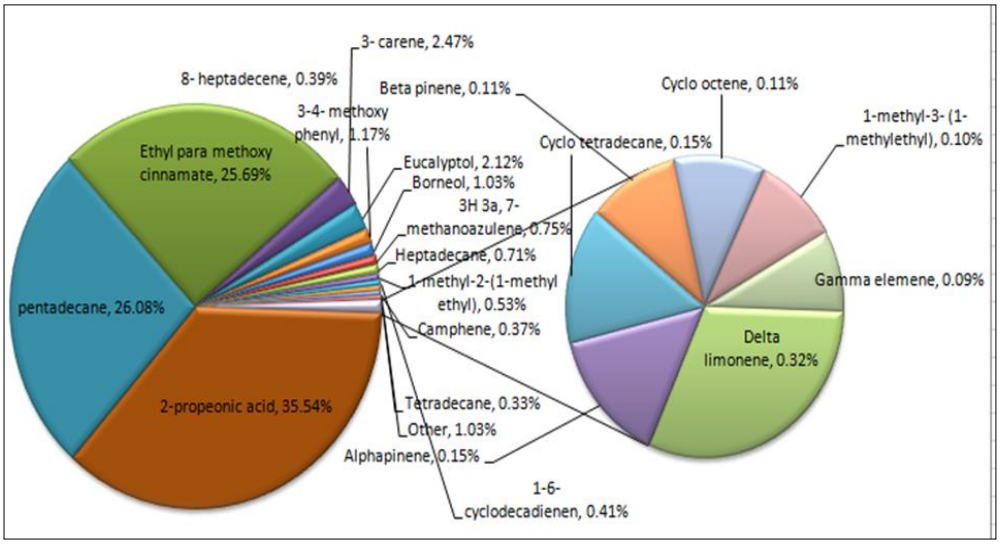
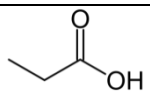
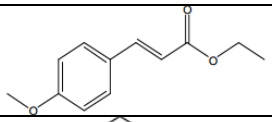
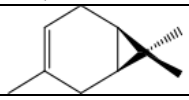
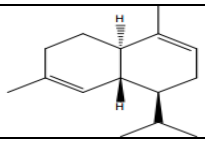
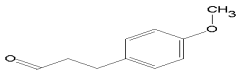
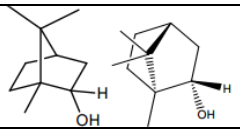
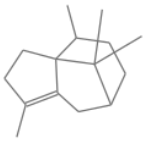
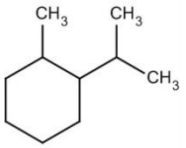
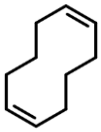
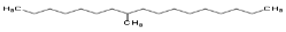
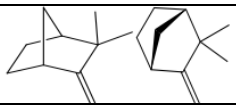
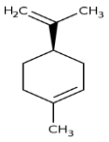
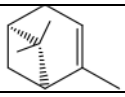
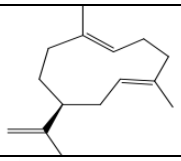
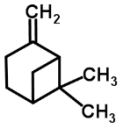
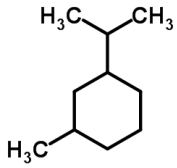
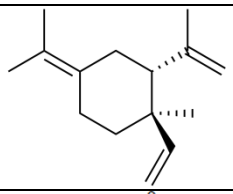
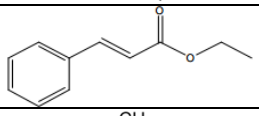
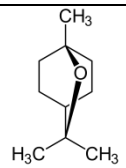
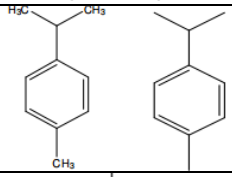
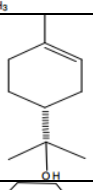
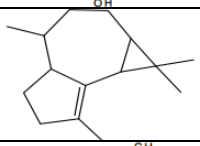
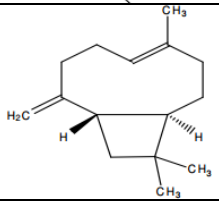


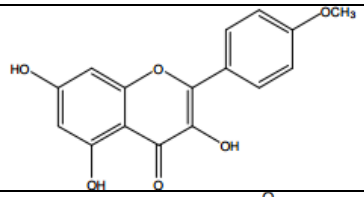
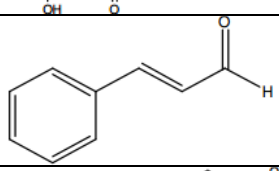
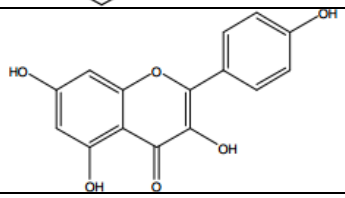
Fig 2: Percent composition of essential oil content of KG extracts [14]

Table 1: Important phytoconstituents isolated from KG extracts [10, 14, 15]

Serial No	Name	Structure
1.	2- propeonic acid	
2.	Pentade cane	
3.	Ethyl paramethoxycinnamate	
4.	3 - carene	

5.	Cadinenes	
6.	3, 4- methoxyphenyl	
7.	Borneol	
8.	3H- 3a, 7- methanoazulene	
9.	Heptade cane	
10.	1- methyl, 2-(1- methylethyl)	
11.	1,6- cyclodecadienen	
12.	8- heptade cane	
13.	Camphene	
14.	Tetradecane	
15.	Delta limonene	
16.	Alpha pinene	

17.	Germacrene	
18.	Beta pinene	
19.	Cyclooctene	
20.	1- methyl- 3-(1- methylethyl)	
21.	Gamma elemene	
22.	Ethyl cinnamate	
23.	Eucalyptol or 1, 8 cineole	
24.	Cymene	
25.	Alpha Terpineol	
26.	Alpha Gurjunene	
27.	Beta-Caryophyllen	

28.	Kaempferide	
29.	Cinnamaldehyde	
30.	Kaempferol	

Pharmacological activities of *Kaempferia galangal*

Antimicrobial activity

Kaempferia galangal extract has the ability to inhibit *Lactobacillus acidophilus*, bacteria responsible for dental caries. The extract of KG was made using three solvents namely dichloromethane, aquades and ethanol; amongst which the ethanolic extract was most effective against *Lactobacillus acidophilus*, exhibiting better antibacterial activity than penicillin but less than erythromycin [16]. Essential oils extracted from the rhizomes of *Kaempferia galanga* were tested for antibacterial activity against both gram positive (*Staphylococcus aureus and Bacillus cereus*) and gram-negative bacteria (*Pseudomonas aeruginosa and Escheria coli*). *K. galanga* did not exhibit any antibacterial activity against the bacterial strain tested [17]. The in vitro antibacterial activities of *Kaempferia galanga* leaves and rhizomes (extracted in acetone) were tested against gram positive bacteria such as *Staphylococcus aureus (S.aureus), Bacillus cereus (B. cereus)* and gram negative bacteria such as *Escherichia coli (E. coli), Pseudomonas aureus (P. aureus), Shigella dysenteriae (S. dysenteriae)* and *Klebsiella pneumoniae (K. pneumoniae)* using disc diffusion method. All the extracts showed moderate activity against all the strains of bacteria mentioned except *Klebsiella pneumoniae (K. pneumoniae)* [18]. Ethyl p-methoxy cinnamate (EPMC) extracted from *Kaempferia galanga L.* rhizome was screened for its antibacterial activity. The results indicated that EPMC compound with concentration up to 1.2 and 2.4% have minimum inhibitory concentration (MIC) against *S.aureus and S. epidermidis*; while for *P.acne*, the concentrations are 0.6, 1.2 and 2.4%. In conclusion, it can be said that EPMC 1.2% can be regarded as risk free since there were no reports of allergic irritation [19]. The antimicrobial activity of *Kaempferia galanga* rhizome was investigated using methanol, ethanol, chloroform, petroleum ether and aqueous extracts of it. Ten bacterial pathogenic species (*Staphylococcus aureus, Streptococcus faecalis, Bacillus cereus, Bacillus subtilis, Enterobacter aerogenes, Salmonella typhi, Escherichia coli, Klebsiella pneumoniae, Pesudomonas aeruginosa* and *Vibrio cholerae)* and four fungal species (*Aspergillus niger, A. flavus, A.fumigatus and Candida albicans)* were assayed using disc diffusion method and then the zone of inhibition was analysed. All the extracts showed good to moderate antifungal and antibacterial activity; although ethanolic extract depicted most prominent antibacterial activity against *S.aureus* [20].

Cytotoxic and Antineoplastic Activity

Cytotoxic activities were assessed by standard MTT and SRB measures against four cancerous viz., DU145, PA1, SW620, B16F10 and a normal Vero cell cultures by using the extracts of the rhizome from *Kaempferia galanga* and also some progressive extracts like petroleum ether, ethyl acetic acid derivation and ethanol. In case of cancer cells Successive ethyl acetate extract appeared particular poisonous quality but for normal cells they were less harmful [21]. Extracts of *K. galanga* and its bioactive compound EPMC exhibited moderate cytotoxic activity against human CCA tumor (CL-6) cell line [22]. KG extracts possesses inhibitory impact on tumor-promoting arrange of neoplasia and hence detailed as anti-neoplastic [23]. Hindrance of TPA (12-O tetradecanoyl-phorbol-13-acetate) initiated activation of epsteinbarr virus early antigen in Raji cells is caused due to the methanolic extracts of KG that is assessed by circuitous immunofluorescent assay and western blot and display fractional inhibitory impact on tumor-promoting stage [23]., 80% restraint is perceived at a dose of 320 µg/ml. At a dose of 640 µg/ml it can be escalates to a most extreme level of 90% [23]. Colorimetric tetrazolium salt assay of the methanolic extracts of KG Linn showed that at doses more than 250 µg/ml may grant inhibitory impact on human cardiac fibroblast (cell line HCF-7) and human T cell leukemia (HT-29 cell line) [24]. KG extract, ethyl-p methoxycinnamate follows a dose dependent manner and exhibits the inhibition in proliferation of human hepatocellular liver carcinoma (Hep G2 cell line) [25]. Dash and his colleagues reported that by using lethality bioassay technique in case of brine shrimp nauplii we can see that the LC50 esteem of acetonic leaf extract was 4.78 µg/ml. Thus it is reported that all the extracts display direct cytotoxic action while equating with vincristine sulphate, a standard drug which has an LC50 esteem of 0.52µg/ml [26].

Anti-inflammatory and analgesic activity

Alcoholic extract of Kaempferia galanga was tested for

analgesic and antiinflammatory activities in animal models, where two doses 600 mg/kg and 1200 mg/kg of plant extract exhibited significant anti-inflammatory activity in carrageenan model and cotton pellet granuloma model and significant analgesic activity in tail flick model and hot plate model [27]. In traditional medicine, leaves and rhizomes of *Kaempferia galanga* are used to treat headache, swelling, stomach ache, toothache and rheumatism [28]. When given subcutaneously in doses of 30, 100 and 300 mg/kg, the aqueous extracts of *Kaempferia galanga* leaves show significant anti-inflammatory effect in rats in a dose dependent manner [29]. The capacity of the extracts to block abdominal constriction, hot plate and formaline test indicates that analgesic activity has both central mechanism, involving opioid receptors, and peripheral mechanism that involves cyclooxygenase pathway [30]. The methanol extract of *Kaempferia galanga* at doses of 100 and 200mg/kg demonstrated anti-inflammatory activity which seemed to be dose and time dependent [31]. Ethyl-p-methoxycinnamate is an anti-inflammatory constituent which can be isolated from Kaempferia galanga L. Extracts [32]. *Kaempferia galanga* inhibits inflammation by suppressing interleukin-1, tumor necrosis factor-α, and angiogenesis by blocking endothelial functions [33]. *Kaempferia galanga* L. extract has the same effectiveness as meloxicam in reducing pain, stiffness in patient with knee osteoarthritis [34].

Antidiarrheal activity

According to Ali *et al*, experimental animals were randomly selected and divided into four groups denoted as control, standard and test samples (group-I and group-II) and consisting of 6 mice in each group. Mice were fasted for 18h before the test with free access to water. Control (water 5ml/kg), standard (Loperamide 3mg/kg) and test samples *Kaempferia galangal* (100 and 200 mg/kg) were administered orally. Then 1 h later, 0.3ml castor oil was administered orally to each mouse to induce diarrhea. The total numbers of both dry and wet faeces excreted by the animals were counted every hour for a period of 4 h. The total number of diarrheal faeces of the control group was considered 100%. In this castor oil-induced diarrhea experiment, the mice group that did not receive the plant extracts showed typical diarrheal signs and symptoms such as watery and frequent defecation. The effects of *Kaempferia galangal* were found to be statistically significant ($p < 0.05$-0.001) which shows it has the power to inhibit the severity of diarrhea induced by castor oil [35].

Anthelmintic activity

According to Dash *et al*, test samples of extract of *Kaempferia galanga* were prepared at 25, 50 and 100mg/ml concentration in normal saline water and approximately equal size of six earthworms (*Pheretima posthuma*) were placed in each beaker containing 50ml of above test solutions of extract. Albendazole (10 mg/ml) was used as a reference standard and normal saline water as control. Time for death of worms were recorded after ascertaining that worms neither moved when shaken vigorously nor when dipped in warm water (50ºC). Eventually, dose-dependent paralysis followed by death occurred in each crude extract containing 25, 50 and 100mg/ml. At 25mg/ml concentration in all extracts (ACR = Acetone extract of rhizome, PEF = Petroleum ether fraction of rhizome, CHF=Chloroform fraction of rhizome, MEF=Methanol fraction of rhizome) showed paralytic effect approximately in 48 min and took more than 80 min for death sentence. However, for 50 and 100mg/ml concentration, within a very short time each extract successfully produced paralytic effect followed by death. The reference drug albendazole also showed strong anthelmintic action. As a whole, different extracts of *Kaempferia galanga* showed anthelmintic activity in a dose- dependent manner [36].

Mosquito repellent and larvicidal activity

The essential oil of *Kaempferia galanga* rhizomes demonstrated contact toxicity against the booklouse, *Liposcelisbos Trychophila* Badonnel, with an LC50 value of 68.6 g/cm^2. Four active constituents, including 1,8 single, ethyl cinnamate, ethyl-methoxycinnamate, and *trans*-cinnamaldehyde were isolated from the essential oil and identified. Ethyl cinnamate (LC50 21.4 g/cm2) exhibited stronger contact toxicity than both ethyl –methoxycinnamate (LC50 44.6) and *trans*-cinnamaldehyde (LC50 43.4 g/cm2) while 1,8-cineole showed weak acute toxicity[37].Methanolic extract of Kaempferia galanga showed the significant toxicity effect at different concentrations (0.25%, 0.5%, 1.0%, 2.0% and 4.0%) against the different instar (I, II, III and IV) larvae and pupae of Anopheles stephensi. The LC50 and LC90 values of *K. galanga* for I instar larvae were 0.63 %,3.15 %, II instar 0.86 %, 3.66%, III instar 1.12%, 4.14%, IV instar 1.43%, 4.55%, respectively. The LC50 and LC90 values of pupae were 0.69%, 3.05% [38]. The extracts have shown significant larvicidal activity even against pyrethroid resistant strains of *A. aegypti* [14]. Ethyl-*p*methoxycinnamate, ethyl-cinnamate, 3-carene, 2- propionic acid and pentadecane are mainly responsible for larvicidal activity [14, 39]. Ethyl-*p*-methoxycinnamate has shown more larvicidal activity (LC 50 = 12.3 to 20.7 mg/L) against *A. aegypti*, *O. togo i*and *C. pipenspallens*, on the other hand, ethyl-cinnamate and 3-carene have more larvicidal activity (LC 50 = 24.1 and 21.6 mg/L respectively) against *C. pipenspallens*but less activity (LC50 = 40 to 60 mg/L) against *A. aegypti*and *O. togio*[39].Essential oils extracted from the rhizomes of *K. galanga* have shown considerable repellent and larvicidal activity against a number of mosquito species, including *Aedes togoi*, *Culex pipenspallens* [40], *Aedes aegypti* [40, 41, 42], *Armigeres subalbatus*, *Anopheles barbirostris*, *Anopheles aconitus*, *Mansonia uniformis*, *Culex quinquefasciatus*, *Culex gelidus* and *Culex tritaeniorhynchus* [42].Without irritating human skin for about 3 h, these essential oils exert repellent effect against *A. aegypti* (effective dose (ED 50) = 30.73 µg/cm2) [42].This protection time increases further by the addition of 10% vanillin [41]. Methanolic extracts of *K. galanga* showed 100% mortality, at a concentration of 100 ppm against *A. aegypti*, *A. togoi* and *C. pipenspallens*, which reduced up to 78% at the concentration of 50 ppm [40]. A study on the possible mechanism of toxicity of ethanolic extracts of *K. galangal* against *C. quinquefasciatus* larvae has revealed that the possible site of action is the anal gills of *C. quinquefasciatus* where it causes the destruction of ionic regulation [43].

Sedative activity

The acetone extracts of rhizome (200 mg/kg) and leaf (200 mg/kg) of *Kaempferia galangal* exhibited significant ($p < 0.05$ and $p < 0.001$) reduction of onset and duration of thiopental sodium induced sleeping time. The extracts possess central nervous system (CNS) depressant properties which support its use in traditional medicine [44]. Inhalation of hexane extract of *K. galanga* has shown considerable decrease in locomotor activity in rats, at doses ranging from 1.5 to 10 g. This sedative activity is due to ethyl trans-*p*-methoxycinamate and ethyl-cinnamate that inhibits locomotor activity at doses of 0.0014 and 0.0012 mg, respectively [13].

Conclusion

Kaempferia galanga is an important herb with many valuable medicinal properties. The plants *K. galanga* or aromatic ginger are already has gained the acceptances worldwide because of their medicinal activity, odor and tastes. The further and advanced study and research could improve and enhance their application in more broader and appropriate range. The review presented here dealt with the taxonomy, ethnobotany, phytochemistry and pharmacology of *K. galanga.* However, the extensive information provided here in all these aspects will be useful as a concrete support for future experimental studies targeting *K. galanga.*

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