**ABSTRACT**

*Etlingera elatior* are large ginger plants growing in clumps. Rhizomes are stout, strongly aromatic and found just below ground level. Crushed leaves emit a pleasant sour fragrance which is distinctive of the species. Leaves are entirely green with young leaves sometimes flushed pink. Inflorescences, borne on erect stalks protruding from the ground, are large and attractive with showy bracts. Native to Malaysia and Indonesia, *E. elatior* is widely cultivated in Southeast Asia. The species is used as food, condiment, medicine, and ornament. The current knowledge on the phytochemistry of leaves, inflorescences, and rhizomes of *E. elatior* is reviewed. Some insights on the pharmacological properties of the species are discussed. They include antioxidant, antibacterial, antifungal, tyrosinase inhibition, cytotoxic, and hepatoprotective activities.

**Key words:** *Etlingera elatior*, phytochemistry, pharmacological properties, leaves, rhizomes, inflorescences

**INTRODUCTION**

Gingers are perennial herbs belonging to the family Zingiberaceae. They produce aromatic rhizomes that are subterranean or above ground.[1] Each rhizome can produce leafy shoots. Inflorescences are terminal, borne either on leafy shoots or on erect shoots near the base of the plant. Ginger rhizomes are consumed as spice or condiment and are used in traditional medicine. In recent years, gingers are gaining popularity as ornamental plants as their inflorescences and foliage are colourful and attractive. They belong to three tribes, namely, Alpiniae, Zingibereae, and Hedychieae.[2]

*Etlingera* Giseke is a genus of the tribe Alpiniae. *Etlingera* species are tall forest plants with larger species growing up to 6 m in height.[3-5] Inflorescences are raised above the ground in the *Phaeomeria* group or just appearing at soil level in the *Achasma* group.[4-5] The varying shades of pink and red colours of bracts and flowers make *Etlingera* species very attractive plants. About 15 *Etlingera* species have been recorded in Peninsular Malaysia.[5] They have traditional and commercial uses as food, condiment, medicine, and ornament.[6]

*Etlingera elatior* (Jack) Smith or torch ginger grows up to 5-6 m tall forming clumps.[3,5] Rhizomes are stout (3-4 cm in diameter), strongly aromatic and found just below ground level. Leaves are entirely green (up to 80 × 18 cm) with young leaves sometimes flushed pink (Figure 1). Petioles are 2.5-3.5 cm in length. Borne on stalks protruding from the ground, inflorescences are large and attractive with showy bracts which are pink to red and sometimes white (Figure 2). Young inflorescences have a spear-like head. Crushed leaves and inflorescences emit a distinctive pleasant sour fragrance. The species is native to Malaysia and Indonesia. Synonyms of *E. elatior* are *Alpinia elatior*, *Elettaria speciosa*, *Nicolaia elatior*, *Nicolaia speciosa*, and *Phaeomeria speciosa*.

Plants of *E. elatior* are widely cultivated in Southeast Asia. Farms in Australia and Hawaii are cultivating the species and selling its inflorescences as cut flowers commercially.[2] Young inflorescences are a compulsory ingredient of sour curry and other spicy dishes. In Malaysia, the hearts of young shoots, inflorescences and fruits are consumed by the indigenous communities as condiment, eaten raw or cooked as vegetable.[1] A decoction of fruits is used to treat earache while a decoction of leaves is applied for cleaning wounds.[8] Leaves are also used by post-partum women and mixed with other aromatic herbs in water for bathing to remove body odour.
PHYTOCHEMISTRY

The phytochemistry of *E. elatior* has received some attention in recent years. From the rhizomes, two new and six known compounds of diarylheptanoids, labdane diterpenoids, and steroids have been isolated.[9] The known compounds were demethoxycurcumin, stigmast-4-en-3-one, stigmast-4-ene-3,6-dione, stigmast-4-en-6β-ol, 3-one, 5α,8α-epidioxyergosta-6,22-dien-3β-ol, and 1,7-bis(4-hydroxyphenyl)-1,4,6-heptatrien-3-one. The new compounds were 1,7-bis(4-hydroxyphenyl)-2,4,6-heptatrienone and 16-hydroxylabda-8(17),11,13-trien-16,15-olide.

Phytochemical screening of methanol extracts of *E. elatior* inflorescences showed the presence of flavonoids, terpenoids, saponins, tannins and carbohydrates.[10] Phenolic, flavonoid, anthocyanin and tannin contents of inflorescences were 361 mg GAE/100 g, 763 mg QE/100 g, 5.1 mg CGE/100 g, and 468 mg CE/100 g, respectively.[11] The phenolic content of inflorescences of 1.2 mg/100 g was attributed mainly to quercetin.[12] From the leaves of *E. elatior*, flavonoids of kaempferol 3-glucuronide, quercetin 3-glucuronide, quercetin 3-glucoside, and quercetin 3-rhamnoside have been reported.[13] Other phenolic compounds isolated from the leaves were caffeoylquinic acids of 3-O-caffeoylquinic acid, 5-O-caffeoylquinic acid (chlorogenic acid), and 5-O-caffeoylquinic acid methyl ester, and flavonoids of isoquercitrin, quercitrin, and (+)-catechin.[14-15]

Chlorogenic acid (CGA) in leaves of *E. elatior* (294 mg CGA/100 g) was significantly higher in content than flowers of *Lonicera japonica* or Japanese honeysuckle (173 mg CGA/100 g), the commercial source. A protocol to produce a standardised extract of CGA with 40% w/w purity from leaves of *E. elatior* was developed.[14] Freeze drying of leaves of *E. elatior* followed by extraction with 30% ethanol, and sequential fractionation using Diaion HP-20 and Sephadex LH-20 yielded a CGA extract with 40% w/w purity. CGA fractions had antioxidant, antibacterial, and tyrosinase inhibition properties. The entire fractionation process took only 6.5 h, using gravity flow. From 50 g of leaves, the final yield of CGA extract was 0.2 g (0.4%). CGA content of the standardised extract from leaves (40%) of *E. elatior* is 1.6 times that of commercial extracts from honeysuckle flowers (25%). Inflorescences of *E. elatior* had flavonoid content consisting of 286 and 21 mg/kg of kaempferol and quercetin, respectively.[16]

Composition of essential oils varied with different parts of *E. elatior*.[17] Major components of leaves, stems, flowers and rhizomes were (E)-β-farnesene, β-pinene, 1,1-dodecanediol diacetate, cyclododecane, and (E)-5-dodecane. Essential oils isolated from inflorescences of *E. elatior* revealed that the main compounds were dodecanol (alcohol), dodecanal (aldehyde), and α-pinene (terpenoid).[18-19] Major constituents of oils from leaves of *E. elatior* have been reported to be β-pinene (24.9%) and 1-dodecene (24.3%),[20] and to be sesquiterpenes comprising (E)-farnesene (13.6%) and (E)-caryophyllene (8.6%).[21]

PHarmacology

Antioxidant activity

Analysis of diarylheptanoids isolated from rhizomes of *E. elatior* using the ferric thiocyanate assay showed that
their antioxidant activity is higher than that of α-tocopherol.[23] Lipid peroxidation inhibition of diarylheptanoids ranged from 92-94% compared to 70% of α-tocopherol. The radical scavenging activity of methanol extracts from inflorescences of *E. elatior* (76.3%) was reported to be comparable to that of butylated hydroxytoluene (86.8%).[10]

There are several publications on the antioxidant properties (AOP) of leaves of *Ettlingera* with emphasis on *E. elatior*. AOP were evaluated in terms of total phenolic content (TPC), radical scavenging activity expressed as ascorbic equivalent antioxidant capacity (AEAC), and ferric reducing power (FRP). Of five *Ettlingera* species screened, *E. elatior* had the highest TPC, AEAC, and FRP.[22] Values were 3550 GAE/100 g, 3750 mg AA/100 g, and 20 GAE/g, respectively. Screening of AOP of leaves of 26 ginger species belonging to nine genera and three tribes showed that *Ettlingera* had the highest values followed by *Alpinia* and *Hedychium*.[23] Boesenbergia, Curcuma, Elettariopsis, Kaempferia, Staphochlamys, and Zingiber had much lower values. The outstanding AOP of *Ettlingera* species were attributed to their size and growth habitat. Plants of *Ettlingera* are the largest among the gingers and can grow up to 6 m in height. They grow in gaps of disturbed forest and are continually exposed to direct sunlight. The other genera are small- to medium-sized herbs. Larger ginger plants growing in exposed forest sites have stronger AOP than smaller plants growing in shaded sites.

Leaves of *E. elatior* which had the highest TPC and AEAC were eight times higher than rhizomes.[23] Leaves had significantly higher TPC, AEAC, and FRP than inflorescences and rhizomes.[23] Ranking was in the order: leaves > inflorescences > rhizomes. It has been reported much greater concentrations of flavones and flavonols occur in leaves which are exposed to sunlight.[24] Only trace amounts were found in unexposed parts below the soil surface which include roots and rhizomes.

Leaves of highland populations of *Ettlingera* species were found to have higher TPC and AEAC than lowland counterparts.[23] Values of *E. elatior* in the highland were 3550 mg GAE/100 g and 3750 mg AA/100 g compared to 2390 mg GAE/100 g and 2280 mg AA/100 g in the lowland, respectively. Higher altitudes seem to trigger an adaptive response in leaves of *Ettlingera* species. The stronger AOP of highland over lowland plant populations might be due to environmental factors such as higher UV-B radiation and lower air temperature.[25-27]

The effects of different drying methods on the AOP of leaves of *E. elatior* have been reported.[24] All methods of thermal drying (microwave, oven, and sun drying) of leaves resulted in drastic declines in TPC, AEAC, and FRP. Many studies have reported losses in antioxidant properties of plant samples following thermal treatments. Loss in AOP of heat-treated samples has been attributed to thermal degradation of phenolic compounds, loss of antioxidant enzyme activities and degradative enzymes.[29,30] Declines are often accompanied by the loss of other bioactive properties.[31]

Of the non-thermal drying methods (air and freeze drying), significant losses were observed in air-dried leaves of *E. elatior*. Declines in AOP resulting from air drying could be due to enzymatic degradation as the process was carried out at room temperature and takes several days for samples to dry. There were significant gains in TPC (21%), AEAC (31%), and FRP (26%) for freeze-dried leaves compared to fresh leaves. After one week storage, AOP of freeze-dried leaves of *E. elatior* remained significantly higher than those of fresh leaves as control. TPC and antioxidant activity of freeze-dried inflorescences have been reported to be nine and eight times that of fresh samples.[32]

There is no thermal degradation in freeze drying and neither does the process allow degradative enzymes to function.[23] Furthermore, freeze drying is known to have high extraction efficiency because ice crystals formed within the plant matrix can rupture cell structure, which allows exit of cellular components and access of solvent, and consequently better extraction.[33] The HPLC chromatogram of leaves of *E. elatior*, which showed greater amounts of minor compounds following freeze drying, supported this inference.[28] Freeze drying remains the best method of drying foods as the quality of freeze-dried products is comparable to fresh products.[34]

**Antibacterial activity**

Ethanol extracts from inflorescences of *E. elatior* displayed antibacterial activity.[23] Minimum inhibitory concentration (MIC) was 200 μg/ml against *Pseudomonas aeruginosa*, 400 μg/ml against *Bacillus megaterium*, and 800 μg/ml against *Escherichia coli*. Methanol extracts inhibited *Staphylococcus aureus*, *Bacillus thuringiensis*, *E. coli*, *Bacillus subtilis*, and *Proteus mirabilis* with MIC ranging from 1.56 to 50.0 mg/ml.[34] Leaves of *E. elatior* exhibited moderate inhibition against Gram-positive bacteria of *Bacillus cereus*, *Micrococcus luteus*, and *S. aureus* with no activity against Gram-negative bacteria of *E. coli*, *P. aeruginosa*, and *Salmonella choleraesuis*.[22] Essential oils from *E. elatior* leaves inhibited methicillin-resistant *S. aureus* (MRSA) with no activity on *P. aeruginosa*, *S. choleareus*, and *B. subtilis*.[24] Rich in sesquiterpenes (24.5%), leaf oils of *E. elatior* inhibited Gram-positive *B. cereus*, *M. luteus*, and *S. aureus* with MIC values of 25, 6.3, and 50 mg/ml, respectively.[23]

**Antifungal activity**

Twelve Thai medicinal plants were tested for antifungal activity against *Colletotrichum gloeosporioides*.[34] Hexane extracts
from young inflorescences of *E. elatior* demonstrated high inhibitory activity of mycelial growth with EC$_{50}$ value of 804 µg/ml. When screened against a broad range of human pathogenic fungi, ethanol extracts of fruits and rhizomes of *E. elatior* did not show any antifungal activity.[37]

**Tyrosinase inhibition activity**

Methanol leaf extracts of five *Etlingera* species were analysed for tyrosinase inhibition (TI) activity using the modified dopachrome method with L-DOPA as substrate.[23] TI was strongest in leaves of *E. elatior* (55%) which was significantly higher than leaves of *Hibiscus tiliaceus* (44%) used as positive control. TI values of the other four *Etlingera* species ranged from 22-49%.

**Cytotoxic activity**

Of the diarylheptanoids, labdane diterpenoids, and steroids isolated from rhizomes of *E. elatior*, stigmaster-4-en-6β-ol-3-one displayed high anti-tumour activity using the Epstein-Barr virus (EBV) activation assay.[38] Ethyl acetate extracts showed strong cytotoxic activity against CEM-SS and MCF-7 cell lines using the methyl thiazole tetrazolium (MTT) assay. IC$_{50}$ of rhizome extracts was 4.0 and 6.3 mg/ml, respectively, compared to tamoxifen with IC$_{50}$ of 30 and 15 µM, respectively.

Ethanol extracts from *E. elatior* leaves and inflorescences are cytotoxic to HeLa cells.[35,39] The cytotoxic dose (CD$_{50}$) was in the range of 10 to 30 µg/ml. Methanol leaf extracts did not exhibit cytotoxic effect on normal WRL-68 (human liver) and Vero (African green monkey kidney) cells.[15]

Screening of 38 Thai edible plants for activity toward EBV activation in Raji cells induced by 12-O-tetradecanoylphorbol-13-acetate (TPA) showed that leaf and stem extracts of *E. elatior* were moderately active while rhizome extracts were weakly active.[40]

**Hepatoprotective activity**

The protective activity of ethanol extracts of *E. elatior* inflorescences against hepatotoxicity induced by lead acetate in male Sprague-Dawley rats has been reported.[41] Treatment with the extract significantly reduced hepatic lipid hydroperoxides and protein carbonyl content in the serum, increased antioxidant enzyme levels in the liver, and decreased lead levels in the blood. The study concluded that the hepatoprotective effect against lead toxicity in rats may be attributed to the powerful lead chelating ability of the extract. A related study examined the effect of *E. elatior* extracts on the bone marrow of male Sprague-Dawley rats exposed to lead acetate toxicity.[42] It similarly concluded that the species has a powerful antioxidant effect which protects bone marrow oxidative damage induced by lead acetate.

**CONCLUSION**

Plants of *E. elatior* are tall ginger plants that are widely cultivated for their inflorescences which have traditional and commercial uses as food, condiment, medicine, and ornament. From the rhizomes, compounds of diarylheptanoids, labdane diterpenoids, and steroids have been isolated. Phytochemical screening of inflorescences showed the presence of flavonoids, terpenoids, saponins, tannins, and carbohydrates. From the leaves, flavonoids and caffeoylquinic acids have been reported. Leaves of *E. elatior* had the strongest AOP out of 26 ginger species screened. Leaves had significantly stronger AOP than inflorescences and rhizomes with highland populations have higher values than lowland counterparts. Heat drying methods adversely affected the AOP of leaves while freeze drying enhanced their values. The various plant parts of *E. elatior* have antibacterial, antifungal, tyrosinase inhibition, cytotoxic, and hepatoprotective properties. With strong antioxidant and other pharmacological properties, the species has great potential to be developed into functional and other health products. To date, this report represents the most comprehensive review of the phytochemistry and pharmacological properties of *E. elatior*.

**REFERENCES**


