# 23 Curry Leaf

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## 23.1. Introduction

*Murraya koenigii*, commonly known as the curry leaf tree, is a native of India, Sri Lanka and other South Asian countries. Curry leaves are grown throughout India and they adorn every backyard, especially in the southern states, where most cuisines are prepared with the subtle flavouring of this highly aromatic leafy spice. The leaves are used to flavour a range of dishes and typically these are fried in oil until crisp to impart flavour to all types of curry preparations (Choudhury and Garg, 2007). Fresh leaves release a strong aroma while cooling. The plant has also been used in traditional Indian medicine systems for a variety of ailments. The oil derived from the leaves is also used in the perfume and soap industries (Shanthala and Prakash, 2005).

## 23.2. Botany

Curry leaf (*M. koenigii* L. Spreng) belongs to the citrus family, Rutaceae. It is a small tree maintained, under cultivation, as a small shrub. Some trees have been observed at a height of more than 5 m. Under cultivation, they are maintained below 2.5 m high. The leaves are exstipulate, bipinnately compound, 30 cm long, each bearing 24 leaflets, having reticulate venation; the leaflets are lanceolate, 4.9 cm long, 1.8 cm broad, having 0.5 cm-long petioles (Parmar and Kaushal, 1982). Lalitha *et al.* (1997) and Lal *et al.* (2000) described the diversity in the genetic resources. Reisch *et al.* (1994c) studied the chemotypes available in Sri Lanka.

## 23.3. Composition

The leaf extract of curry leaf has been reported to contain moisture (66.3%), protein (1%), fat (1%), carbohydrate (16%), fibre (6.4%) and mineral matter (4.2%). The main minerals per 100 g of leaves are calcium (810 mg), phosphorus (600 mg) and iron (2.1 mg). The vitamins in the leaves are carotene (12,600 i.u.), nicotinic acid (2.3 mg) and vitamin C (4 mg) (Anon., 1962; Kumar *et al.*, 1999). The extract also contains oxalic acid, which reduces the availability of calcium. The contents are total oxalate (1.352%) and soluble oxalate (1.155%) (Ananthasamy *et al.*, 1960; Walde *et al.*, 2005). The effects of storage temperature on the nutritive value were studied by Palaniswamy *et al.* (2002). Reisch *et al.* (1994a) found the furocoumarins in the seeds.

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## 23.4. Chemistry

### Volatile oils

Philip (1981) reported that young leaves contained more volatile oil and oleoresin than mature leaves. Table 23.1 describes the variability in the percentage composition of constituents in young and old leaves (Hiremath *et al.*, 1997; Mallavarapu *et al.*, 1999). The variation in oil recovery and composition during dehydration was described by Madalageri *et al.* (1996).

Terpenes are the main constituents of the volatile essential oil of *M. koenigii* leaves, which are used for curry flavouring (MacLeod and Pieris, 1982). The oil of *M. koenigii* produces less than 4% of other components, with eight monoterpene hydrocarbons (about 16%) and 17 sesquiterpene hydrocarbons (about 80%). The major constituents responsible for aroma are β-caryophyllene, β-gurjunene, β-elemene, β-phellandrene and β-thujene (Kumar *et al.*, 1999). The volatile oils from the leaves of six species of the genus *Murraya* have been studied by GC-MS and about 60 monoterpene and sesquiterpenes components were identified. From these results, and published data on other species, it appears that the oils are either predominantly sesquiterpenoid or monoterpenoid in nature. The distinction between the two oil types coincides with other chemical data that support the division of the genus into two sections, *Murraya* and *Bergera* (Lal *et al.*, 2000; Ramalakshmi *et al.*, 2000).

**Table 23.1.** Volatile constituents in young and old leaves of *Murraya koenigii*.

| Constituent | Content | |
|---|---|---|
| | Young leaves | Old leaves |
| Caryophyllene (%) | 26.3 | – |
| Cadinene (%) | 18.2 | – |
| Cadinol (%) | 12.8 | – |
| D-Sabinene (%) | 9.2 | 31.8–44.8 |
| Dipentene (%) | 6.8 | – |
| D-α-Pinene (%) | 5.5 | 19.0–19.7 |
| β-Pinene (%) | – | 4.2–4.7 |
| D-1-α-Phellandrene (%) | 4.6 | – |
| β-Phellandrene (%) | – | 6.5–7.9 |
| D-α-Terpinene (%) | 3.2 | 1.3–4.3 |
| Δ-Terpinene (%) | – | 3.9–7.1 |
| Terpinene-4-ol (%) | – | 5.2–9.9 |
| Lauric acid (%) | 2.7 | – |
| Palmitic acid (%) | 3.4 | – |

*Source*: Philip (1981); Mallavarapu *et al.* (1999).

The flavour volatile constituents of the seed cotyledons, fruits and leaves of *M. koenigii* L. were analysed by GC-MS and compared with curry leaf flavour constituents (Walde *et al.*, 2005). These consist of monoterpene hydrocarbons, oxygenated monoterpenes and sesquiterpenes. The major constituents of curry leaf are monoterpenes (70%), seed cotyledons (86%) constituting α-pinene (52%) and *cis*-β-ocimene (34%); raw fruit oil containing monoterpenes (80%) and oxygenated monoterpenes (4.8%); and fruit pulp oil containing monoterpenes (61%).

The curry leaf plant is highly valued for its characteristic aroma and medicinal value. A number of leaf essential oil constituents and carbazole alkaloids have been extracted from the plant (Hiremath and Madalageri, 1997). A large number of studies have been carried out on the chemical composition of various parts of the curry leaf plant (Raina *et al.*, 2002). It has been reported that the leaves contain 34 compounds, which constitute about 97.4% of the oil. The major constituents identified were α-pinene (51.7%), sabinene (10.5%), β-pinene (9.8%), β-caryophyllene (5.5%), limonene (5.4%), bornyl acetate (1.8%), terpinen-4-ol (1.3%), γ-terpinene (1.2%) and α-humulene (1.2%) (Rana *et al.*, 2004), while an earlier study by Wong and Tie (1993) identified 62 components, the main constituents being β-phellandrene (24.4%), α-pinene (17.5%), β-caryophyllene (7.3%) and terpinen-4-ol (6.1%). Mallavarapu *et al.* (2000) identified 48 constituents of the leaf essential oil, representing 95% of the essential oil, and 42 constituents of the fruit essential oil, accounting for 98.5%. The major constituents of the leaf essential oil were α-pinene (9%), α-phellandrene (6.1%), β-phellandrene (50.1%), (*E*)-β-ocimene (7.1%) and β-caryophyllene (4.9%). The main constituents of the fruit essential

oil were α-pinene (48.1%), β-pinene (7.1%), myrcene (3.1%), β-phellandrene (26%), γ-terpinene (3%) and β-caryophyllene (3%).

Variation in chemical composition has been observed among different agroclimatic locations. Analyses of the essential oil from the leaves of *M. koenigii* growing in southern Nigeria revealed an oil composition of predominantly sesquiterpenes (89.1%). The main components of the oil were β-caryophyllene (20.5%), bicyclogermacrene (9.9%), α-cadinol (7.3%), caryophyllene epoxide (6.4%), β-selinene (6.2%) and α-humulene (5%) (Onayade and Adebajo, 2000). Studies on the volatile oil in the leaves of *M. koenigii* grown in Sri Lanka, isolated by steam distillation, identified 36 out of 53 compounds detected. The major constituents were β-thujene (5.8%), β-phellandrene (18.9%), (*E*)-β-ocimene (12.7%), β-caryophyllene (23.3%), α-humulene (4.3%) and β-bisabolene (3.14%) (Paranagama *et al.*, 2002). The major volatile compounds from *M. koenigii* are given in Fig. 23.1.

Wong and Chee (1996) analysed the volatile constituents of *M. koenigii* flowers by capillary GC and GC-MS following isolation by solvent extraction. Forty-eight compounds were identified, monoterpenoids and sesquiterpenoids accounting for 34.4 and 43.9% of the total volatiles, respectively. The major components were β-caryophyllene (24.2%), (*E*)-β-ocimene (18%) and linalool (8%). In a later study, Walde *et al.* (2006) isolated the volatiles of fresh leaf stalks and flowers by a simultaneous distillation and extraction method, followed by GC-MS analysis. Thirty-one components were identified in the leaf stalk oil, constituting 88.1% of the volatile oil. The major components were the mono- and sesquiterpene hydrocarbons (66.7%), the major ones of which were α-pinene (24.2%), β-pinene (6.9%), α-phellandrene (7.3%) and α-copaene (8.9%). In addition, the oil had nine oxygenated monoterpenes (14.2%) and four sesquiterpene alcohols (8.1%). In the flower oil, 24 components were identified (constituting 91.8% of the volatile oil), which constituted 87% mono- and sesquiterpenes. The major compounds in this class were *cis*-ocimene (34.1%), α-pinene (19.1%), γ-terpinene (6.7%) and β-caryophyllene (9.5%). It also contained seven oxygenated monoterpenes and three oxygenated sesquiterpenes,

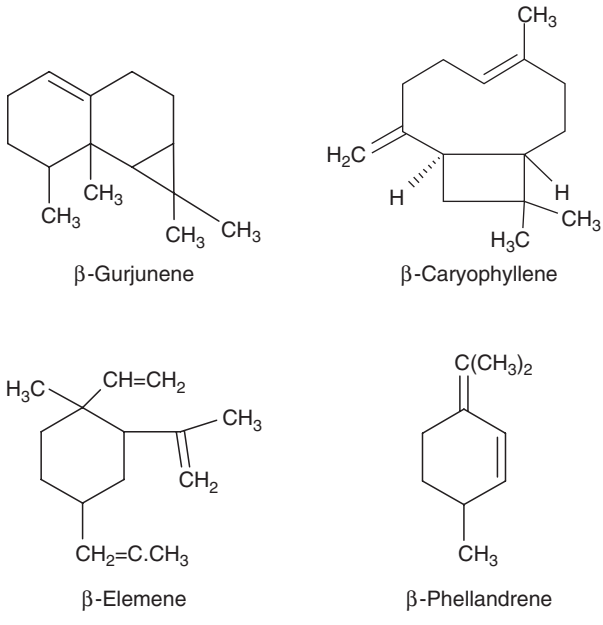


**Fig. 23.1.** Volatile compounds from *Murraya koenigii*.

constituting 4.7% of the oil. The larger number of oxygenated mono- and sesquiterpenes present appeared to be responsible for the intense odour associated with the stalk and flower parts of *M. koenigii*, as compared with the leaf. Table 23.2 describes the volatile component of seeds, fruit pulp, raw fruit and leaves and Table 23.3 illustrates the leaf oil composition in plants grown in Nigeria. β-Caryophyllene, bicyclogermacrene, caryophyllene epoxide, α-cadinol and α-humulene are some of the prominent compounds in Nigerian oil.

### Carbazole alkaloids

Interestingly, the first discovery of carbazoles from plant sources, girinimbine, was reported in *M. Koenigii* (Chakraborty *et al.*, 1964). Since then, this species has proved to be a major source of carbazole alkaloids (Chakraborty, 1993).

From the stem bark, a new carbazole derivative, named murrayanine, has been isolated. It has been formulated as 1-methoxy-3-formylcarbazole (I) (Chakraborty *et al.*, 1965). Roy and Chakraborty (1974) reported the isolation of mahanimbine. The structure of a new hexacyclic carbazole alkaloid, isomurrayazoline, from stem bark has been shown to be 9a,10,11,12,13,13a-hexahydro-5,9,9,12-tetramethyl-1 (Bhattacharya *et al.*, 1982). The isolation of mahanimbine, girinimbine and two new carbazole alkaloids, isomahanimbine and koenimbidine, from the leaves and roots of the curry leaf plant has been reported. Spectroscopic and degradative evidence supports structures for girinimbine, mahanimbine, isomahanimbine, koenimbidine and murrayacine (Joshi *et al.*, 1970). The ethanolic extract of the leaves afforded a new carbazole alkaloid, which was identified as bismurrayafoline E on the basis of spectroscopic analysis (Nutan *et al.*, 1999). DL-*O*-Methylmahanine, 8-hydroxymahanimbine and pyranylcarbazole were synthesized from carabazole (Anwer *et al.*, 1972). 3-Methylcarbazoles were oxidized to the corresponding derivatives with excess 2,3-dichloro-5-6-dicynobezoquinonine. Murraycine was prepared similarly by oxidation of girinimbine (Anwer *et al.*, 1973). New biogenetically significant constituents, namely, 3-methyl carbazole and glycozoline, were reported by Adesina *et al.* (1988). A biogenetically important carbazole alkaloid from curry leaf was reported by Bhattacharyya *et al.* (1986). Its isolation supports the proposal that the pyranocarbazoles are formed from 2-hydroxy-3-methylcarbazole by the incorporation of $C_5$ and $C_{10}$ units (Bhattacharyya and Chakraborty, 1984; Reisch *et al.*, 1994b).

Koenoline, a further cytotoxic carbazole alkaloid from *M. koenigii*, was described by

**Table 23.2.** Volatile components of seeds, fruit pulp, raw fruits and leaves of *Murraya koenigii*.

| Compound | Seed oil (%) | Fruit pulp oil (%) | Raw fruit oil (%) | Leaf oil (%) |
|---|---|---|---|---|
| α-Pinene | 51.60 | 21.8 | 46.32 | 16.79 |
| Camphene | 0.95 | – | 0.72 | 1.31 |
| β-Pinene | 12.56 | 4.6 | 10.10 | 4.72 |
| β-Myrcene | 7.29 | 3.34 | 5.92 | 2.65 |
| α-Phellandrene | 0.45 | 4.95 | 1.97 | 2.96 |
| *cis*-β-Ocimene | 0.31 | 1.27 | 13.94 | 28.49 |
| *trans*-β-Ocimene | 2.45 | 39.17 | 7.41 | 6.42 |
| γ-Terpinene | 9.28 | 5.49 | 0.41 | 6.63 |
| *cis*-Linalool oxide | 0.22 | 1.39 | 3.96 | – |
| *trans*-Linalool oxide | 5.82 | – | 0.82 | – |
| Linalool | 1.24 | – | 0.20 | – |
| α-Copaene | 6.00 | 10.32 | 5.04 | 20.16 |
| β-Caryophellene | 1.07 | 1.82 | 0.83 | 3.49 |
| Isocaryophyllene | 0.24 | 1.22 | – | 2.38 |

**Table 23.3.** Composition of leaf essential oil of *Murraya koenigii* grown in Nigeria.

| Constituent[1] | Content (% of total oil) | Constituent | Content (% of total oil) |
|---|---|---|---|
| α-Pinene | 1.5 | β-Selinene | 6.2 |
| Sabinene | t | Zingiberene* | t |
| β-Pinene | t | Bicyclogermacrene | 9.9 |
| Myrcene | t | α-Muurolene* | t |
| α-Phellandrene | t | γ-Cadinene | 0.2 |
| *p*-Cymene | t | β-Sesquiphellandrene* | t |
| Limonene | 2.2 | δ-Cadinene | 0.4 |
| β-Phellandrene* | t | Cadina-1,4-diene | 0.2 |
| 1,8-Cineole* | t | ε-Nerolidol | 1.7 |
| *cis*-β-Ocimene | t | Un (O-seq) | 0.9 |
| Dihydrotagetone | 1.3 | Ledol | 0.4 |
| Myrcene epoxide | t | Spathulenol | 2.0 |
| Linalool | 0.2 | Un (O-seq) caryophyllene | 1.3 |
| Camphor | t | Epoxide | 6.4 |
| Terpinen-4-ol | 0.4 | Globulol* | t |
| α-Terpineol | 0.2 | Un (O-seq) | 2.0 |
| Thymol | 0.4 | Widdrol | 1.1 |
| α-Copaene | t | Cedrol | 1.5 |
| β-Bourbounene | t | Humulene epoxide | 2.7 |
| β-Elemene | 2.2 | *epi*-Cubenol | 2.1 |
| β-Cubebene* | t | Selina-1,3,7(11)-trien-8-one | 3.2 |
| β-Caryophellene | 20.5 | Ledol isomer* | t |
| β-Cedrene* | t | α-Eudesmol* | t |
| Bicycloelemene | 2.4 | α-Cadinol | 7.3 |
| *epi*-Santalene | 1.0 | Selin-11-en-4α-ol | 1.6 |
| *trans*-β-Farnesene | 1.8 | Un (O-seq) | 0.6 |
| α-Humulene | 5.0 | α-Santalol | 0.3 |
| Alloaromadendrene | 0.2 | *epi*-Santalol | 0.3 |
| Curcumene | 0.5 | β-Santalol | 0.4 |
| γ-Muurolene | 1.4 | Un (O-seq) | 0.8 |
| Ledene | 0.6 | | |
| Germacrene-B | t | | |

*Source*: Onayade and Adebajo (2000).

*Note*: [1]Listed in order of elution on Durabond-DBI GC column; marked (*) constituents were determined on CP-wax 52 cb GC column; t = trace amount (< 0.2%), Un (O-seq) = unidentified oxygen-containing sesquiterpene. All Un (O-seq) < 0.5% are omitted from above list.

Fiebig *et al*. (1985). It exhibited cytotoxic activity against certain cell cultures. Its structure was established as 1-methoxy-3-hydroxymethylcarbazole by analysis of spectroscopic data and was confirmed by partial synthesis from murrayanine isolated from *M. siamensis* roots. Koenoline exhibited cytotoxic activity against the KB cell-culture test system. Bhattacharyya and Chakraborty (1984) described mukonal, a probable biogenetic intermediate of pyranocarbazole alkaloids, from stem bark of *M. koenigii*. The structure of the compound has been established as 2-hydroxy-3-formyl carbazole based on physical (UV, IR, $^{1}$H NMR, $^{13}$C NMR and mass spectrometry) and chemical transformations. Mukherjee *et al*. (1983) described mukonicine, another carbazole alkaloid from the leaves of *M. koenigii*. From physical methods coupled with chemical evidence, its structure was determined as 1,2-[2:2-dimethyl-$\Delta^{3}$-pyrano]-3-methyl-6,

8 dimethoxycarbazole. A new $C_{23}$-carbazole alkaloid, mahanimbinol, was isolated from the stem of the Indian curry leaf plant, *M. koenigii*. It is a key precursor in the biosynthesis of some 20 other carbazole alkaloids reported previously from this plant (Rao *et al.*, 1980). Structure and synthesis of mukonine, a new carbazole alkaloid from *M. koenigii* [stem bark], was described by Chakraborty *et al.* (1978). The structure of murrayacinine, a carbazole alkaloid from *M. koenigii*, was described by Chakraborty *et al.* (1974). Apoptosis of curry leaf carbazole alkaloids was observed by Ito *et al.* (2006). The structures of carbazole alkaloids from *M. koenigii* are illustrated in Fig. 23.2.

Minor furocoumarins reported from seeds include xanthotoxin, isobyakangelicol, phellopterin, gosferol, neobyakangelicol, byakangelicol, byakangelicin and isogosferol (Adebajo and Reisch, 2000).

The chemical constituents of stem bark were reported by Sukari *et al.* (2001). The carbazole alkaloids, e.g. mahanimbine, girinimbine and murrayanine, were isolated and characterized from the petroleum ether extract of bark. A minor alkaloid, mahanine, was isolated from *M. koenigii* leaves (Rahman *et al.*, 1988). Based on silica gel column chromatography (CC) and preparative thin-layer chromatography (TLC) analyses, Ito *et al.* (1993) isolated 16 known carbazoles and carbazolequinones, three new monomeric and five new binary carbazole alkaloids (mukoenine-A, -B and -C, murrastifoline-F, *bis*-2-hydroxy-3-methylcarbazole, bismahanine,

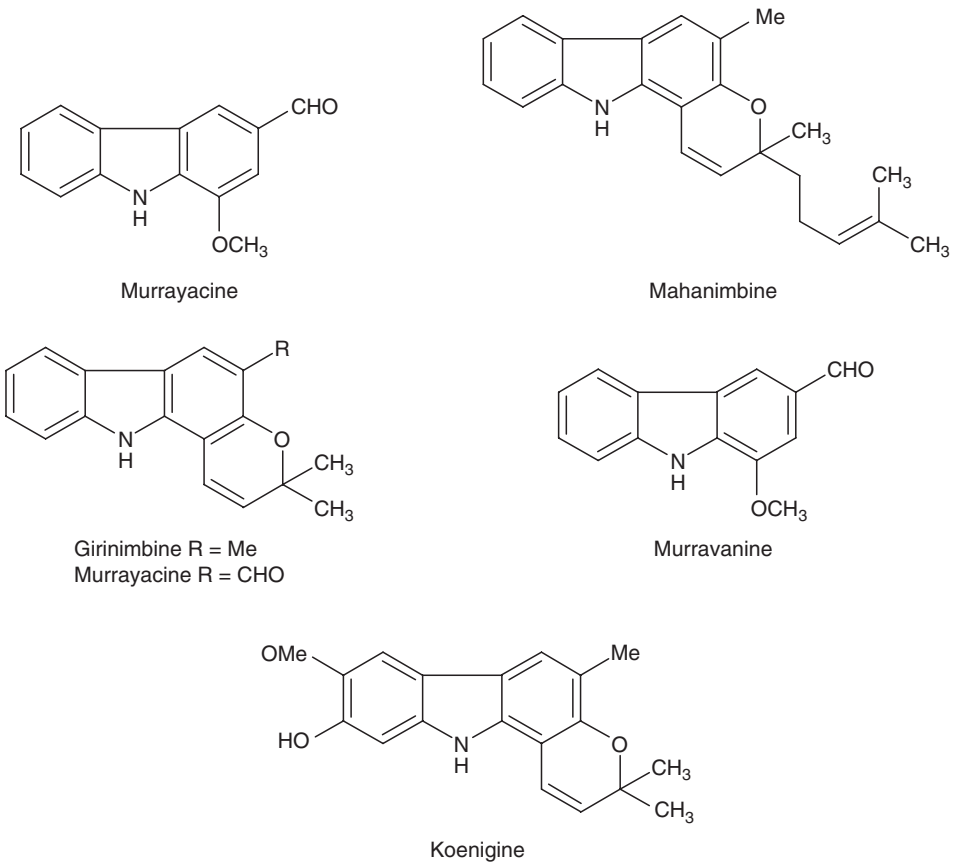


**Fig. 23.2.** Carbazole alkaloids from *Murraya koenigii*.

bikoeniquinone-A and bismurrayaquinone-A, respectively) from the acetone extracts of root and stem bark. Bikoeniquinone-A and bismurrayaquinone-A were found to contain a carbazole-1,4-quinone skeleton as a basic structural unit. Bhattacharyya *et al.* (1994) isolated two carbazole alkaloids from the stem bark. They were identified as 2-methoxy carbazole-3-methyl carboxylate and 1-hydroxy-3-methyl carbazole from spectral and chemical evidence. Wang *et al.* (2003) isolated two new carbazole alkaloids named murrayanine (1) and 8,8′-biskoenigine (2) from *M. koenigii*. The structure elucidations for 1 and 2 were carried out on the basis of 1D and 2D NMR experiments. Compound 1 was a novel carbazole alkaloid with a rare phenylpropanyl substitution and compound 2 was a symmetrical dimer of the carbazole alkaloid, koenigine. The synthesis of 2 from koenigine was carried out through oxidative coupling using a solid-state reaction. Chakraborty *et al.* (1997) isolated two new alkaloids, 9-carbethoxy-3-methylcarbazole and 9-formyl-3-methylcarbazole, and a known metabolite, 3-methyl-carbazole, from the roots of *M. koenigii*. All three compounds were identified by detailed spectral analyses, including 2D NMR studies, and their structures confirmed by synthesis. Of the two metabolites, the 9-formyl compound showed antitumour properties.

### *Lipids*

Lipids from dry seed were extracted and the quantity of availability was around 4.4%, consisting of 85.4% neutral lipids, 5.1% glycolipids and 9.5% phospholipids. The fatty acid composition of total lipids indicated oleic, linoleic and palmitic acids to be the major components (Hemavathy, 1991).

## 23.5. Medicinal and Pharmacological Uses

Curry leaf has been used in folk medicine in China and other Asian countries as an analgesic, astringent, antidysenteric, antioxidant, febrifuge, hypolipidaemic, hypoglycaemic, for improvement of vision, to treat night-blindness and for regulation of fertility (Palaniswamy *et al.*, 2003). The cortex, roots and leaves of *M. koenigii*, a plant endemic to southern India, are used in Ayurvedic and Yunani (Unani) medicines for the treatment of febrile disorders, dysentery, diarrhoea and inflammation of the gums. The essential oil of this plant is thought to have antibacterial and antifungal properties. The essential oil obtained from the leaves by steam distillation was found to contain 11-selinen-4α,5α,7β,10β-4-ol (kongol or 11-eudesmen-4-α-ol) and the azulene derivative, 10-aromadendranol (globulol) (Wagner *et al.*, 1995). It is used in traditional medicine to treat constipation, colic, diarrhoea and hiccups. An aqueous extract of the leaves (200–800 mg/kg), collected from a garden in Sri Lanka, was administered to ethanol-treated rats. The extracts inhibited the development of ethanol-induced lesions in the corpus of the stomach (Ratnasooriya *et al.*, 1995). Differentiation in the pharmaceutical potential of the *Murraya* species was described by Kong *et al.* (1986).

The fresh juice of curry leaves, mixed with limejuice and sugar, cures morning sickness, nausea and vomiting due to indigestion. Chewing tender leaves helps to control diarrhoea, whereas matured leaves are beneficial in controlling diabetes and weight loss. Leaves ground with turmeric and taken daily are an effective remedy for allergic reactions. Curry leaves and black pepper beaten with sour curd are beneficial for indigestion (Irani, 2005).

### Antioxidant

Five carbazole alkaloids isolated from the $CH_2Cl_2$ extract and their structures, namely, euchrestine B (compound 1), bismurrayafoline E (compound 2), mahanine (compound 3), mahanimbicine (compound 4) and mahanimbine (compound 5), exhibited antioxidative properties (Nakatani, 2000; Tachibana *et al.*, 2001). The levels of antioxidant vitamins in fresh curry leaves were

9744 ng of lutein, 212 ng of α-tocopherol and 183 ng of β-carotene per gram fresh weight (Palaniswamy *et al.*, 2003). The carbazole, mahanimbine, from curry leaf exhibits antioxidant activity (Ramsewak *et al.*, 1999).

### Antimicrobial

Curry leaf has been shown to possess more antibacterial activity and less antifungal activity (Aqil and Ahmad, 2003). The compounds such as isomahanine and murrayanol isolated from the $CCl_4$ fraction exhibited good activity against 11 of 14 tested bacterial species (Nutan *et al.*, 1998). Chowdhury *et al.* (2001) isolated two new alkaloids, 1-formyl-3-methoxy-6-methylcarbazole (compound 1) and 6,7-dimethoxy-1-hydroxy-3-methylcarbazole (compound 2), from the leaves of *M. koenigii*. Compound 2 was found to be active against Gram-positive and Gram-negative bacteria and fungi. Rahman and Gray (2005) isolated a benzoisofuranone derivative, 3ε(1ε-hydroxyethyl)-7-hydroxy-1-isobenzofuranone, and a dimeric carbazole alkaloid, 3,3'-[oxybis (methylene)] *bis*-(9-methoxy-9*H*-carbazole), along with six known carbazole alkaloids and three known steroids from the stem bark of *M. koenigii*. The minimum inhibitory concentrations (MIC) of these compounds were found to be in the range 3.13–100 μg/ml when tested on *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, *Proteus vulgaris*, *Aspergillus niger and Candida albicans*. Based on ethnomedicine, *M. koenigii* (L.) Spreng. is used as a stimulant, antidysentery and for the management of diabetes mellitus (Adebajo *et al.*, 2004). The petroleum ether and crude chloroform extracts of curry leaf exhibited weak antibacterial activity against *B. cereus* (Sukari *et al.*, 2001).

The three bioactive carbazole alkaloids, e.g. mahanimbine, murrayanol and mahanine, were found to be mosquitocidal and antimicrobial. The antioxidant activity of carbazoles (1,1-diphenyl-2-picryl hydrazyl: DPH) from *M. koenigii* was found to be in order ascorbic acid > bismurraya foline E > euchestine B, mahanine and α-tocopherol > BHT > mahanimbirine and mahanimbine (Walde *et al.*, 2005).

### Anti-inflammatory

Bioassay-guided fractionation of the acetone extract of the fresh leaves of *M. koenigii* resulted in the isolation of three bioactive carbazole alkaloids (mahanimbine, murrayanol and mahanine). Murrayanol showed activity against human prostaglandin H synthase (hPGHS-1) and hPGHS-2 (IC50 values of 109 and 208 μg/ml, respectively) in an anti-inflammatory assay (Ramsewak *et al.*, 1999). Essential oils (1.4% v/w) from *M. koenigii* leaves showed significant anti-inflammatory and analgesic activities in mice (Maiti *et al.*, 2004).

### Antidiabetic

It is reported that curry leaves slow down the starch to glucose breakdown in diabetic patients. It has been recommended to promote them as preferable food adjuvants for diabetic patients (Grover *et al.*, 2002). In mild and moderate diabetic rats, feeding of 5, 10 and 15% diets caused a maximum reduction in blood sugar by 13.1, 16.3 and 21.4% (NS, $P < 0.05$ and 0.005) and 3.2, 5.58 and 8.21% (NS), respectively (Yadav *et al.*, 2002). The methanol extract of curry leaf was more effective in lowering the blood glucose levels in diabetic rats compared with the aqueous extract (Vinuthan *et al.*, 2007). There are a large number of reports on the use of curry leaf for diabetes. However, Iyer and Mani (1990), Adebajo *et al.* (2004) and Yadav *et al.* (2004) did not find any effect on diabetes parameters. This may be due to the quantity of curry leaf required to bring down the glucose level.

### Pesticidal properties

The essential oil of curry leaf is composed of many chemicals with a multispectral

activity. The monoterpene hydrocarbons and sesquiterpene hydrocarbons play a major role in this activity (Ray and Srivastava, 2006). Its leaves have been studied for their antifungal activity against three plant pathogenic fungi, i.e. *Rhizoctonia solani, R. bataticola* (*Macrophomina phaseolina*) and *Helminthosporium oryzae* (*Cochliobolus miyabeanus*). The essential oils had shown fungitoxity of more than 50% at 2000 ppm concentration. Benzene extract was found to be more antifungal than hexane extract. The antifungal activity of pure carbazoles, e.g. koenimbine, was improved by their derivatization into corresponding *N*-methyl koenimbine and *N*-methyl koenidine. However, hydrogenation of the pure carbazoles into dihydro derivatives caused reduction in fungitoxicity (Ray and Srivastava, 2006). It has also been proved to be effective against *Rhizopus stolonifer* (*R. stolonifer* var. *stolonifer*) and *Gloeosporium psidii* (*Colletotrichum coccodes*) infecting guava (Dwivedi *et al.*, 2002). The leaves and their extract were found to have nematicidal action (Padhi and Behera, 2000; Pandey, 2000, 2005).

The oil was toxic at concentrations of 340 ppm, and the varying effects of some Sri Lankan essential oils on oviposition and progeny production was reported by Pathak *et al.* (1997) and Abeywickrama *et al.* (2003). It has also been reported to be useful against the cabbage pests, *Pieris brassicae* and *Plutella xylostella* (Mehta *et al.*, 2005; Facknath, 2006), against the mustard aphid, *Lipaphis erysimi* (Srivastava and Kumar, 1999), and against *Callosobruchus chinensis* developing in green gram (*Vigna radiata*) and chickpea seeds.

It has great potential for use in mosquito control programmes. The three carbazole compounds (mahanimbine, murrayanol and mahanine) exhibited activity against *Aedes aegyptii* and against a battery of microorganisms (Ramsewak *et al.*, 1999). The *Murraya* extract was most toxic against *A. aegypti*, followed by *Culex quinquefasciatus* and *Anopheles stephensi* (Pathak *et al.*, 2000).

### Other uses

#### *Industrial uses*

The major constituents of the oil are *cis*-caryophyllene (11.74%), dipentene (11.3%), α-eudesmol (9.61%), isocaryophyllene (8.41%) and β-elemene (7.09%). The composition of the oil suggests that it may find application as a fixative in soap and detergent perfumes (Chowdhury, 2000).

#### *Plant growth inhibitors*

Curry leaf has been reported to contain plant growth inhibitors. Bhattacharya *et al.* (1989) described the isolation and characterization of two coumarins present in *M. koenigii* bark. The growth-inhibitory properties are comparable to those of other coumarins, such as psoralen and xanthotoxin.

#### *Effect on female sex hormones*

The plant is reported to have an effect on the ovarian hormone profile and reproductive performance of animals (Mehrotra *et al.*, 2003, 2005).

## 23.6. Conclusion

*M. koenigii* (Linn), commonly known as the curry leaf plant, is highly valued for its characteristic aroma and medicinal properties. Its leaves are used extensively for culinary purposes, especially in curries and chutneys, but also in vegetable, fish and meat dishes, pickles, buttermilk preparations, curry powder blends, etc. The major volatile components in curry leaf are α-pinene, β-caryophyllene, (*E*)-β-ocimene, linalool and β-phellandrene. *M. koenigii* is a rich source of carbazole alkaloids. Its leaves, roots and bark are a tonic, stomachic and carminative. It is shown to possess a hypocholesterol effect and many other health benefits. The crop promises great scope in various biochemical and industrial applications in the future.

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