



Review Article

A review on curry leaves (*Murraya koenigii*): versatile multi-potential medicinal plant

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ABSTRACT

Plants have been used in traditional medicine for several thousand years. India is perhaps the largest producer of medicinal herbs and is rightly called the "Botanical garden of the World". Ayurveda -The Indian traditional system of medicine claims to cure and control various diseases by means of herbal medicines. *Murraya koenigii* (Curry Leaves/Kadhi Patta/Mitha Nimba/Giri Nimba) is native to India and it is found almost everywhere in the Indian subcontinent excluding the higher levels of Himalayas. The curry tree is having many diseases protecting ingredients (natural compounds) which can be used as a natural source to make newer, alternative and innovative medicines. Curry leaves used traditionally as antiemetic, anti-diarrhoeal, febrifuge and blood purifier. The whole plant is considered to be a tonic and stomachic. Curry leaves are found to be effective as antioxidant, antidiabetic, antibacterial, antihypertensive, cytotoxic and also in the treatment of bronchial respiratory difficulties. The leaves are used traditionally as a spice in curry and other eatables. The present review incorporates the description of *M. koenigii*, its phytochemical constituents and various pharmacological activities of isolated compounds as well as bioactivity of extract studies carried out by various numbers of laboratories.

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INTRODUCTION

India is a country with a vast reserve of medicinal herbs, which contain numerous biologically active compounds that are helpful in improving the life and treatment of the diseases. Most of the population relies upon herbal medicines because they have been considered as safe, effective and economical. *Murraya koenigii* (Curry Leaves/Kadhi Patta/Mitha Nimba/Giri Nimba) is one such medicinally important herb which is widely used as spice, condiments and also used to treat various diseases in India. It is a staple in Indian dishes and is well known for its subtle flavor and used confidently in daily cooking. Curry leaves contain many important ingredients like carbohydrates, proteins, fibres, calcium, phosphorus, iron, magnesium, copper,

minerals and vitamins like nicotinic acid, vitamin B, C, A and E, antioxidants, plant sterols, glycosides and flavonoids. The oil is used externally for bruises, eruption, in soap and perfume industry (Prajapati et al., 2003). The phytoconstituents isolated so far from the leaves are alkaloids viz., mahanine (Narasimhan et al., 1970), koenine, koenigine, koenidine (Narasimhan et al., 1975), girinimbiol, girinimibine (Adebajo et al., 2006), koenimbine, O-methyl murrayamine A, O-methyl mahanine (Tachibana et al., 2003), isomahanine, bismahanine, bispyrayafoline and other phytoconstituents such as coumarin glycoside viz., scopotin, murrayanine (Adebajo et al., 2000), calcium, phosphorus, iron, thiamine, riboflavin, niacin, vitamin

C, carotene and oxalic acid. The essential oil from leaves yielded di- α -phellandrene, D-sabinene, D- α -pinene, dipentene, D- α -terpinol and caryophyllene (Gopalan et al., 1984). *M. koenigii* is widely used in Indian cookery for centuries and have a versatile role to play in traditional medicine. The plant is credited with tonic and stomachic properties. Bark and roots are used as stimulant and externally to cure eruptions and bites of poisonous animals. Green leaves are eaten raw for cure of dysentery, diarrhoea and for checking vomiting. Leaves and roots are also used traditionally as bitter, anthelmintic, analgesic, curing piles, inflammation, itching and are useful in leucoderma and blood disorders (Nadkarni et al., 1976; Kirtikar et al., 1981).

Taxonomical classification:

Kingdom	: Plantae
Subkingdom	: Tracheobionta
Division	: Magnoliophyta
Class	: Magnoliopsida
Subclass	: Rosidae
Order	: Sapindales
Family	: Rutaceae
Genus	: <i>Murraya</i>
Species	: <i>koenigii</i>

Vernacular Names

English- Curry leaves; Kannada- Karibevu;
Hindi- Karipatta, Mitha nim;
Tamil-Kariveppilai;
Malayalam- Kariveppu; Marathi- Kadhilimb;
Sanskrit- Girinimba;
Telugu- Karepeku; TuluBevusoppu;
German- Curryblatter;

Plant description and habitat

The plant is distributed and cultivated throughout India. It is found wild from Himalaya's, Uttarakhand, Sikkim to Garhwal, Bengal, Assam, Western Ghats and Travancore- Cochin. Propagation is done by seeds, which germinate freely under partial shade. Is also available in another part of Asian region like in moist forests of 500- 1600 mheightin Guangdong, S Hainan, S Yunnan (Xishuangbanna), Bhutan, Laos, Nepal, Pakistan, Sri Lanka, Thailand, Vietnammurraya Together with South Indian immigrants, curry leaves reached Malaysia, South Africa, and Reunion island. Outside the Indian sphere of influence, they are rarely found. *Murraya koenigii* is an unarmed, semi-deciduous aromatic shrub or small tree with slender but strong woody stem and branches covered with dark grey bark, leaves are imparipinnate, glabrous, and very strongly aromatic. Leaflets 9-25 or more, short-stalked, alternate, gland-dotted and strongly aromatic. Flowers are small, white fragrant ebracteate, calyx deeply five cleft, pubescent.

Petal five, free, whitish, glabrous and with dotted glands. Fruits occur in close clusters, small ovoid or sub-globose, glandular, thin pericarp enclosing one or two seeds having spinach green color. The stem of *Murraya koenigii* is an aromatic and more or less deciduous shrub or small tree up to 7 meters in height and 14 to 42 cm in diameter (Raghunathan, et al).



Figure 1. Flowers of *Murraya koenigii*.



Figure 2. Fruits of *Murraya koenigii*.



Figure 3. Leaves of *Murraya koenigii*.

Phytochemistry

Mature leaves contains 63.2 % moisture, 1.15 % total nitrogen, 6.15 % fat, 18.92 % total sugars, 14.6 % starch, 6.8 % crude fiber, ash 13.06 %, acid insoluble ash 1.35 %, alcohol-soluble extractive 1.82%, cold water (20 °C) extractive 27.33% and a maximum of hot water soluble extractive 33.45%. 30 Constituents that have been stimulated the most interest include a wide range of carbazole alkaloids, essential oil, and carotenoids.

The following major group of bioactive constituents summarizes the constituents of *Murraya*.

Carotenoids: Leaves contain 9744 ng of lutein, 212 ng of α -tocopherol and 183 ng of carotene/g of fresh weight (Palaniswamy et al., 2003) 21.4 mg/100 g of total carotene, 7.1 mg/100 g of β -carotene is reported by (Bhaskarachary et al., 1995) E. Siong Tee has reported 14570- μ g/100 g of total carotenoids in leaves as measured by HPLC. Out of total carotenoids, lutein content was 5252 and β -carotene content was 9328 μ g/g (Song, 1991).

Carbazole alkaloids:

Leaves: Tachibana et.al has isolated 8, 10'-{3,3',11, 11'-tetrahydro-9,9' dihydroxy- 3,3',5,8'-tetra methyl -3,3'-bis (4-methyl-3-pentenyl)}bis pyrano (3,2 a) carbazole (a dimeric carbazole alkaloid) from methylene chloride extract of *M. koenigii* leaves together with six known alkaloids; koenimbine, O-methyl murrayamine, Omethyl mahanine, isomahanine and bismahanine and bispyrayafoline (Tachibana et al., 2003; Tachibana et al., 2001). From dried leaves glycozoline, (Adesina et al., 1988) 1-formyl -3 methoxy- 6-methyl carbazole and 6, 7- dimethoxy- 1-hydroxy- 3-methyl carbazole (Chowdhury et al., 2012) was isolated. Koenigine, koenine, koenidine and (-) mahanine were isolated from acetone extract of leaves (Narasimhan et al., 1975). From the hexane extract of leaves Joshi et.al has isolated mahanimbine, isomahanimbine, koenimbidine and murrayacine (Joshi et al., 1970). Isomahanimbicine was isolated from petroleum ether extract of leaves of *M. koenigii* specifically collected in the month of February Euchrestine B, mahanine, mahanimbicine, mahanimbine, bismurrayafoline (Nutan et al., 1999) mahanimbicine, bicyclomahanimbicine (Kureel et al., 1970), cyclomahanimbine, bicyclomahanimbine, mahanimbidine (Kureel et al., 1969), mukonicine (Mukherjee et al., 1983), 8, 8''- bis koenigine, new binary carbazole alkaloid along with its monomer koenigine (Wang et al., 2002) and a minor alkaloid mahanine (Atta-Ur- Rahman et al., 1988) were identified and isolated from leaves of *M. koenigii*, the presence of murrayanine (0.32%), glycoside scopolin (0.25%), free glucose (3.5%) and ash (10.4%). Aerial part is reported to contain murrayanine and 8,8'' bis koenigine . Petroleum ether extract of leaves was used to isolate carbazole alkaloids, mahanimbine (3,5- dimethyl-3-(4-methylpent-3-enyl)-11H-pyrano[5,6-a] carbazole) (Kumar et al., 2010). Methanolic extract of *M. koenigii* was subjected to qualitative thin-layer chromatography and HPLC using the different solvent system by (Gupta, 2007) Spectral analysis (IR, 1H NMR, 13C NMR and MS) was carried out to establish the structure.

The structures of these 6-bioactive compounds confirmed as carbazole alkaloids- Mahanimbine, Girinimbine, Isomahanimbine, Murrayazoline, Murrayazolidine, and Mahanine, by the spectrometric data (Gupta and Singh 2007).

Stem: From alcohol extract of stem bark Saha et al. (1998) has isolated koenigine- quinone A and koenigine quinone B, structures were established as 7- methoxy-3 methyl carbazole- 1,4- quinone and 6, 7-dimethoxy-3-methyl carbazole-1, 4- quinone respectively (Saha et al.,1998) 9- carbethoxy-3-methyl carbazole and 9-formyl -3- methyl carbazole were identified from *M. koenigii* by (Chakraborty et al.,1997) me- 2- methoxy carbazole -3- carboxylate and 1- hydroxy -3- methyl carbazole were isolated from stem bark (Bhattacharya et al., 1994). Mukonal, a probable biogenetic intermediate of pyrano carbazole alkaloid was detected in stem bark (Bhattacharya,1984). From stem bark Murrayazolinol (a minor carbazole alkaloid) (Bhattacharya, 1989), mahanimbicol (Rama Rao et al., 1980), murrayazolidine (Chakraborty et al., 1974; Chakraborty et al., 1970) murrayacinine (Chakraborty et al., 1974), mukonidine (Chakraborty, 1978), murrayazolinine (Chakraborty et al., 1973), murrayanine, girinimbine and mahanimbine (Das, 1965), girinimbicol and mahanimbicol (Reisch et al., 1994) possible biogenetic precursors of girinimbine and mahanimbine) has also been identified and isolated.

Roots: Murrayanol, murrayagetin, marmesin- 1''- O-rutinoside were isolated from root extract (Srivastava et al., 1993). Three monomeric and five binary carbazole alkaloids named mukoenine- A, -B and C and murrastifoline-F. bis-2-hydroxy-3- methyl carbazole, bismahanine, bi koeniquinone- A and bismurrayaquinone A were isolated from root and stem bark (Chihiro et al., 1993). Koenoline (1- methoxy-3-hydroxy methyl carbazole) was isolated from the root bark (Bandyopadhyaya et al., 2001), Mukoline, mukolidine were isolated from the benzene extract of roots (Srivastava et al., 1993). Roots were also found to contain girinimbine.

Seeds: Mahanimbine, girinimbine, koenimbine, isomahanine and mahanine were isolated from seeds of *M. koenigii* from Marassana, Sri Lanka (Johannes, 1994) 2- methoxy-3- methyl carbazole was isolated from petroleum ether extract of seeds (Bhattacharya et al., 1984). Mandal et al.2010 isolated three bioactive carbazole alkaloids, kurryam (I), Koenimbine (II) and koenine (III) with structural confirmation with 2D-NMR spectra (Mandal et al., 2010).

Fruits: Mahanimbine and koenimbine were isolated from petroleum ether extract of fruits (Narsimha et al., 1968). Isomahanine and murrayanol were isolated from

fruits by (Reisch et al., 1992) along with five previously reported carbazole alkaloids mahanimbine, murrayazolidine, girinimbine, koenimbine and mahanine.

Coumarin: Indicolactone, anisoalctone and 2', 3' epoxy indicolactone (a furocoumarin lactone) were isolated from the seeds. This represents the first furocoumarin with a mono terpenoid lactone chain in the genus *Murraya* (Adeleke, 1997) has reported xanthotoxin, isobyanagelicol, byakangelicol and isogosferol as minor furocoumarins in seeds of *M. koenigii* (Adeleke, 2000). Isoheraclenin, isoimperatonin, oxypeucedanin, isopimpinellin, and bergaptan were isolated from seeds of Marassana village, Sri Lanka, suggesting it as a new chemical race (Johannes, 1994). A new coumarin galactoside marmesin- 1'-O- β -D-galactopyranoside, osthol, and umbelliferone were isolated from ethanol stem bark extract (Ravindra, 1992). 3-(1, 1- dimethyl allyl xanthyletin) was isolated from petroleum ether extract of stem bark of *M. koenigii* (Bhattacharya et al., 19984).

Carbazole carboxylic acid: Stem showed the presence of mukeic acid (1- methoxy carbazole- 3- carboxylic acid) (Chowdhury et al., 1971) and mukoeic acid (Chowdhury t al., 1969).

Lipids: Lipid composition of seeds revealed 4.4% of total lipids of which 85.4 % neutral lipids, 5.1 % glycolipids and 9.5 % phospho-lipids. Neutral lipids consisted of 73.9% triacylglycerol, 10.2% free fatty acids and small amounts of diacylglycerols, monoacylglycerols, and sterols. Steryl glucoside and acylated sterylglucoside are major glycolipids. Phospholipids mainly consisted of phosphatidyl ethanolamine and lysophosphatidyl choline (Hemavathy et al., 1991).

Essential oil: Tender leaves contain 0.8% oil as obtained by steam distillation. A number of reports are there on the essential oil composition of leaves obtained by steam distillation, solvent extraction or by fluid carbon dioxide extraction. The oil composition shows phenotypic and genetic variability in diverse origin germplasm lines of curry neem (Lal et al., 2001; Chowdhury et al., 2000; Wong et al., 1993). The chemical composition of the essential oil from leaves of *M. koenigii* varies with variation in agrclimatic and geographical variation. The leaves oil of *Murraya koenigii* from Southern Nigeria (Khan et al., 1997) contains sesquiterpenes (89.1%). The major constituents were β -caryophyllene (20.5%), bicyclogermacrene (9.9%), α -cadinol (7.3%), caryophyllene epoxide (6.4%), β -selinene (6.2%) and humulene (5.0%). The fresh leaves of *Murraya koenigii* from Dehradun (Olubunmi et al., 2001) contains apinene (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%), g-terpinene (1.2%) and α -humulene (1.2%) as the major constituents. The essential oil of leaves consists mainly of monoterpenoids and its oxygenated derivatives. The major oil constituents are β -caryophyllene (35.8%), β -phellendrene (2.57%), α - pinene (0.26%), β -elemene (0.18%) and β thujene (4.12%) as determined by GC- MS of steam distillate. Other components are α -caryopyllene (9.17%), cardinene (8.43%), selinene (8.88), linalool (0.27 %), trans Ocimene (3.12%), gujunene (1.46%). Volatile oil obtained from flowers consists of 34.4% monoterpenoids and 43.9 % of sesquiterpenoids. The major components are β -caryophyllene (24.2%), (E) - β -Ocimene (18.0%) and linalool (8.0%) (Wong et al., 1996). Volatile oil composition of the fruit of *M. koenigii* has been first time reported by Awasthi et.al. As per their studies, hydro distillation of fruits of *Murraya koenigii* resulted in the isolation of 0.13% of oils (w/v) on fresh weight basis respectively. GC and GC-MS analysis resulted in the identification of 73 constituents comprising 98.8% of the oil, of which the major ones were caryophyllene oxide (10.3%), β -caryophyllene (8.5%), tridecanoic acid (8.2 %), dehydroaromadendrene (8.0%), terpinen-4-ol (8.0%), α -cadinol (7.3%), and (Z,E)-farnesol (5.7%) (Awasthi et al., 2011).

Traditional Uses

Traditional system of medicine in Eastern Asia mentions of important uses of this plant i.e. curry leaf tree (*Murraya koenigii* Family: Rutuceae). Leaves of *Murraya koenigii* constitute an important ingredient in the Indian diet to improve appetite and digestion. *Murraya koenigii* is being used as stimulant, antidysentric and for the management of diabetes mellitus. The leaves root and bark possess tonic, stomachic and carminatives properties. Antiemetic property too is seen in the leaves. Purgative properties have been demonstrated in the stem distillate of the leaves. The essential oil is also utilized by soap and cosmetic aromatherapy industry (Rao et al., 2011).

External applications of the leaves have been beneficial in bruises, eruption, and to treat bites of poisonous animals. The leaves being bitter, acrid and cooling have been shown to have cooling, anthelmintic and analgesic action. It is known to cure piles, reduce body heat, thirst, inflammation, and itching. The branches of *Murraya koenigii* are used to strengthen gums, popularly used to clean teeth as dat. (Gupta et al., 2011). It is traditionally used as a whole or in parts as antiemetics, antiarrheal, febrifuge, blood purifier, antifungal, depressant, anti-inflammatory, body aches, for kidney pain and vomiting (Rana et al., 2004; Kumar et al., 1999; Purohit et al., 2009; Iyer et al., 1990; Nutan et al., 1998).

Table 1. Chemical constituents of *M. koenigii*.

S. No.	Chemical constituents	Nature	Plant part (conc.)	Reference
1.	Cadinene (-)	Sesquiterpene	Essential oil (5.2%)	Nigam & Purohit, 1961
2.	Dipentene	Monoterpene	Essentialoil (15.9%)	Nigam & Purohit, 1961
3.	Murrayanine	Carbazole alkaloid	Leaf	Chakraborty et al. 1965
4.	Cyclomahanimbine	Indole alkaloid	Leaf	Kureel et al. 1969
5.	Koenidine	Indole alkaloid	Leaf	Narasimhan et al. 1970
6.	Koenigine	Indole alkaloid	Leaf	Narasimhan et al. 1970
7.	Koenine	Indole alkaloid	Leaf	Narasimhan et al. 1970
8.	Mahanine	Indole alkaloid	Leaf	Narasimhan et al. 1970
9.	Murrayazoline	Carbazole alkaloid	Leaf	Chakraborty et al. 1973
10.	Koenimbine	Indole alkaloid	Leaf	Narasimhan et al. 1975
11.	Mahanimbine (+)	Indole alkaloid	Leaf	Narasimhan et al. 1975
12.	Isomahanimbine (+)	Indole alkaloid	Leaf	Narasimhan et al. 1975
13.	Mahanine (-)	Indole alkaloid	Leaf	Narasimhan et al. 1975
14.	Curryanigine	Indole alkaloid	Stem bark	Narasimhan and Kelkar, 1976
15.	Mukonine	Carbazole alkaloid	Leaf	Roy et al., 1982
16.	Mukolidine	Carbazole alkaloid	Leaf	Roy et al., 1982
17.	Mukonol	Carbazole alkaloid	Leaf	Bhattacharyya & Chakraborty, 1984
18.	2-methoxy-3-methyl carbazole	Carbazole alkaloid	Leaf	Bhattacharyya & Chowdhurys 1985
19.	Murrayazolinol	Carbazole alkaloid	Leaf	Bhattacharyya et al., 1989
20.	Bikoeniquinone	Indole alkaloid	Roots (0.001109%)	Ito et al., 1993

Pharmacological activities

The *Murraya koenigii* possess various pharmacological activities and is known as a multipotential medicinal plant and very commonly used spices and as a home remedy since ancient times as a folk medicine. The pharmacological uses of *Murraya koenigii* can be described in brief such as below.

Antioxidative property

Isolated carbazole alkaloids from dichloromethane extract of leaves of *M. koenigii* were evaluated on the basis of oil stability index together with their radical scavenging ability against DPPH radical on the basis of lag time to reach a steady state. The 12 carbazole were classified into 3 groups. It suggested that an aryl hydroxyl substituent on the carbazole ring plays a role in stabilizing the thermal oxidation and rate of reaction against DPPH radicals. The antioxidative properties of the leaf extracts of *Murraya koenigii* using different solvents were evaluated based on the oil stability index OSI together with their radical scavenging ability against 1, 1- diphenyl-2-picrylhydrazyl (Kureel et al., 1969). Mahanimbine and koenigine, two carbazole alkaloids, isolated from the leaves of *M. koenigii* showed antioxidant activity. Koenigine also showed a high degree of radical scavenging properties (Rao et al., 2006).

Antidiabetic property

Mahanimbine a chemical constituent of *M. koenigii* was isolated from column chromatography of the petroleum ether extract of the dried plant. The anti-diabetic activity was performed on the streptozotocin induced Wistar rats by using pure compound at a dose of 50 mg/kg and 100 mg/kg. The possible mechanism by which the mahanimbine decreases blood sugar level may be by potentiating of insulin effect either by increasing the pancreatic secretion of insulin from beta cells of islets of langerhans or by increasing the peripheral glucose uptake. Mahanimbine showed the appreciable alpha-amylase inhibitory effect as compared with acarbose (Dineshkumar et al., 2010).

Cytotoxic Activity

The isolated carbazole alkaloid as Koenoline from the root bark of *M. koenigii* exhibited the cytotoxic activity against KB cell culture system. Carbazole alkaloids isolated from the stems of *M. koenigii* have effects on the growth of the human leukemia cell line HL-60. Also the carbazole alkaloids, mahanine, Pyrafoline-D and murrayanine-I showed significant cytotoxicity against HL-60 cells and induced the loss of mitochondrial membrane potential (Manfred et al., 1958).

Anticancer activity

Koenoline isolated from root bark exhibited cytotoxic activity against the KB cell culture test system. 9-formyl-3 methyl carbazole displayed weak cytotoxic activity against both mouse melanoma B 16 and Adriamycin resistant P 388 mouse leukemia cell lines (Chakraborty et al., 1997). The effects of extracts of *M. koenigii* in in-vitro (short-term incubation method) and in-vivo (Dalton's ascitic lymphoma (DAL) anticancer models have been evaluated in male Swiss albino mice. DAL cells were injected intraperitoneally (106 cells) to the mice (Nutan et al., 1998). The anticarcinogenic potential of curry leaf using benzo (a) pyrene-induced for stomach and 7, 12 dimethyl Benz (a) anthracene (DMBA) induced skin papillomas was studied. Chemoprotective responses were measured as a decrease in tumor burden (papillomas/mouse) and % of tumor-bearing animals in both the models. Increase in level of acid soluble sulphhydryl compounds, glutathione S-transferase and DTdiaphorases were also measured. Antioxidant parameters (reduced glutathione, Super Oxide dismutase, catalases, and glutathione peroxidase and glutathione reductase) were also elevated (Khan et al., 1997). The in-vitro anti-tumor promoting activity and antioxidant properties of Girinimbine isolated from the stem bark of *Murraya koenigii* was studied by Yih et.al. The in vitro anti-tumor promoting activity of girinimbine was determined by measuring the percentage inhibition of induced early antigen (EA) of EBV on the surface of Raji cells.

Immunomodulatory activity

The methanolic extract of *M. koenigii* showed a significant increase in phagocytic index by rapid removal of carbon particles from bloodstream. The extract also increased the antibody titre against ovalbumin and protection towards cyclophosphamide-induced myelosuppression in albino mice. Oral administration of the aqueous extract of leaves at doses of 250 and 500 mg/kg significantly enhanced the delayed-type hypersensitivity reaction induced by ovalbumin. The extract also potentiated the production of circulating antibody titre significantly in response to ovalbumin (Shah et al., 2010).

Alzheimer disease therapy

Administration ethanolic extract of *M. koenigii* Leaves for 15 d produces significant dose-dependent improvement of memory. The results also indicated to reduce the brain cholinesterase activity and total cholesterol level. Diet rich in *M. koenigii* leaves produced significant dose-dependent improvement in the memory scores of young and aged mice and significantly reduced the amnesia induced by scopolamine (0.4 mg/kg, intraperitoneally) and

diazepam (1 mg/kg, intraperitoneally). Also, brain cholinesterase activity and total cholesterol levels were reduced by the MKL diets. Acetylcholinesterase inhibitory potential of a carbazole alkaloid, mahanimbine, from *Murraya koenigii* leaves was studied by (Kumar et al., 2010) his study is the first to reveal this activity in carbazole alkaloid mahanimbine, isolated from *Murraya koenigii* (Kumar et al., 2010). The effect of total alkaloidal extract from *M. koenigii* leaves (MKA) on cognitive functions and brain cholinesterase activity in mice were determined. In vitro β -secretase 1 (BACE1) inhibitory activity was also evaluated. The brain cholinesterase activity was also reduced significantly by a total alkaloidal extract of *M. koenigii* leaves. The IC50 value of MKA against BACE1 was 1.7 μ g/mL. The study indicates MKA to be a useful remedy in the management of Alzheimer's disease and dementia.

Radiation protection activity

The effect of 4 Gy gamma radiation 30 min after the last injection of 100 mg/kg of methanolic extract of *M. koenigii* for 5 consecutive days was observed on adult Swiss albino mice. The extract itself increased the glutathione and enzymes levels, whereas radiation significantly reduced all values. Pretreatment with the extract reduced lipid peroxidation rate induced by radiation. The result demonstrated that *M. koenigii* leaves possess good antioxidant activity in vitro and are able to protect against radiation-induced depletion in cellular antioxidants (Deepa et al., 2009). The methanolic extract showed protection against gamma radiation and cyclophosphamide-induced chromosomal damage in Swiss albino mice at a single dose of 100 mg/kg body weight (Goswami et al., 2010).

Antiobesity and Antihyperlipidemic activities

The dichloromethane (MKD) and ethyl acetate (MKE) extracts of *Murraya koenigii* leaves significantly reduced the body weight gain, plasma total cholesterol (TC) and triglyceride (TG) levels significantly. The observed antiobesity and antihyperlipidemic activities of these extract are correlated with the carbazole alkaloids, Mahanimbine. When it was given orally (30 mg/kg/day) significantly lowered the body weight gain as well as plasma TC and TG levels. These findings demonstrate the excellent pharmacological potential of mahanimbine to prevent obesity (Birari et al., 2010).

Hepatoprotective activity

The protective nature of *M. koenigii* leaves extract was studied by Gupta et al., 2007. The effect attributed to the combined effect of carbazole alkaloids—Mahanimbine, Girinimbine, Isomahanimbine, Murrayazoline, Murrayazolidine, Mahanine and

ascorbic acid, α -tocopherol and mineral (Zn, Cu, Fe) contents of *M. koenigii* leaves extract. This study proved *M. koenigii* a promising and a rich source of free radical quenchers, which have been mediated through hepatocyte membrane stabilizing activity along with the reduction of fat metabolism (Gupta et al., 2007). The normal morphology of cell was maintained after ethanolic challenge when aqueous extract containing tannins and carbazole alkaloids of *M. koenigii* was given. Hepatoprotective activity was measured with respect to the different parameters studied and maintained normal morphology even after ethanolic challenge to the cells which was comparable to the protection offered by the standard drug L-ornithine-L-aspartate (Gupta et al., 2007; Sathaye et al., 2010). The acetone extract of dried bark powder showed prominent protection of liver cells as compared with the control group and other solvents in CCl₄-induced liver damage (Pande et al., 2009).

Effect on bronchial disorders

The herbal composition containing organic extract of any plant part of *Murraya* (leaves, bark, roots, and seeds) is useful in the treatment and remedy of bronchial respiratory troubles by blocking 5-lipoxygenase activity (Pande et al., 2009).

Cardioprotective activity

The studies indicated that the aqueous extract of Curry leaf protects the rat cardiac tissue against cadmium-induced oxidative stress possibly through its antioxidant activity. Treatment of rats with cadmium also caused alterations in the activities of mitochondrial Krebs's cycle as well as respiratory chain enzymes. All these changes were ameliorated when the rats were pre-treated with an aqueous extract of Curry leaf (Elina et al., 2012).

Antiulcer activity

Antiulcer activity was observed using aqueous extract at doses of 200 and 400 mg/kg. It produced significant inhibition of gastric lesion induced by non-steroidal anti-inflammatory drugs and pylorus ligation-induced ulcer. The extract reduced ulcerative lesion, gastric volume and free and total acidity but raised the pH value of gastric juice in pylorus ligation model. The results obtained suggested that the extract possesses significant antiulcer activity (Patidar et al., 2011).

Antimicrobial and anti-fungal activity

Murrayanine, girinimbine and mahanimbine isolated from stem bark showed antifungal activity against human pathogenic fungi (Chowdhury et al., 2001). 1-formyl-3-methoxy-6-methyl carbazole and 6,7-dimethoxy-1-hydroxy-3-methyl carbazole were reported to possess antibacterial and antifungal

property by Chowdhury et al. (2001). Mahanimbine, murrayanol, and mahanine from fresh leaves showed antimicrobial and topoisomerase I and II inhibitory activity (Ramsewak et al., 1999). Marmesin-1'-O- β -D-galactopyranoside from stem bark showed anti-bacterial, anti-viral and antifungal activity (Kumar et al., 2010). The essential oil was found to be effective against *Rhizoctonia bataticola* (ED 50 0.112 %) and *Helminthosporium oryza* (0.1214%), and the effect is possibly due to the presence of β -caryophyllene and gurunene. Essential oil and aqueous extract of leaf were found active against *Staphylococcus epidermidis*, *S. aureus*, and streptococcus species. Crude extract and chloroform soluble fraction and petroleum ether soluble fraction showed a promising antibacterial activity against all the tested bacteria (Iyer et al., 2010; Srivastava et al., 2001; Akerel et al., 1998). The crude extract of *M. koenigii* roots showed strong antibacterial activity. Extract containing murrayanol and orisomahanine is used as microbicide in a variety of industries due to high safety, strong activity, little odor and without coloring effect.

CONCLUSION

Murraya koenigii was one of the medically beneficial plants which have been used many centuries ago by our ancestors. Keeping in view the tremendous pharmacological activities and availability of literature, *Murraya koenigii* may be utilized to alleviate the symptoms of a variety of diseases as evident from the pre-clinical data. Although crude extract from various parts of *Murraya koenigii* have numerous medical applications, modern drugs can be developed after extensive investigation of its bioactivity, mechanism of action, pharmacotherapeutics, toxicity and after proper standardization and clinical trials. Thus, the importance of this beneficial plant should be emphasized and the bioactive components of *Murraya koenigii* should be analyzed further and, an extensive research and development work should be undertaken on the plant and its products for better economic and therapeutic utilization.

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