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Review on chemistry and pharmacology of *Murraya koenigii* Spreng (Rutaceae)

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Abstract

Murraya koenigii Spreng (Rutaceae), a medicinally important herb of Indian origin, has been used for centuries in the Ayurvedic System of Medicine. The leaves, bark and the roots of the plant are used in indigenous medicine as tonic, stomachic, stimulant and carminative. An infusion of the roasted leaves is used to prevent vomiting. The green tender leaves are eaten raw for the cure of dysentery. The juice of the root is taken to relieve pain associated with kidney ailments. The aim of the present review is to summarize the research related to the chemistry and pharmacology of this popular Indian Species.

Key words: *Murraya koenigii*; Rutaceae; Alkaloid; Chemical structures.

Introduction

India is one of the pioneers in the discovery of herbal medicines for the treatment of various ailments. In the ancient past, India exported many such drug plants to the oriental countries as well as to Greece, Italy, Egypt and Arab countries. With the development of Western therapy people lost interest in herbal medicines. In recent years this trend has reversed. Intensive research in this area is now being pursued all over the world. Serious efforts are being made by the phytochemists and botanists in exploring the plant world to discover more potent drugs from botanical species. These studies have culminated in the isolation, structure elucidation and syntheses of many biologically active compounds. Despite the use of synthetic drugs, much

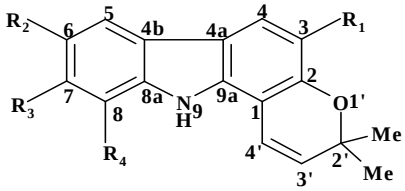
emphasis is being given on herbal medicines because of their ready availability and minimal side effects. Crude drugs in many cases are found to be more potent than the pure drugs, the reason being due to the synergistic action of the other components present which not only enhance the biological activity of the drug but simultaneously lowers the toxic effect. Till now, the traditional herbal drugs remain the major source of health care for more than two thirds of the world's population. The World Health Organisation is strongly advocating for wider acceptance and use of traditional medicine including Ayurveda and Unani [1]. *Murraya koenigii* Spreng (Rutaceae) is one such plant. It is locally called 'Barsunga' in Bengali, 'Kurry patte' in Hindi, 'Karivempu' in Tamil, 'Surabhinimba' in Sanskrit and 'Curry-leaf tree' in English. It grows throughout India and the Andaman Islands [2].

Of the fourteen global species belonging to the genus *Murraya*, only two are available in India, viz. *Murraya koenigii* Spreng and *Murraya paniculata* (Linn) Jack, (syn. with *M. exotica* Linn) [3a]. Of the two the former is more popular due to its large spectrum of medicinal properties and also because of the use of its leaves for centuries as a natural flavouring agent in various curries and food items [3b].

The leaves, bark and the root of the plant are used in indigenous medicine as a tonic, stomachic, stimulant and carminative. An infusion of the roasted leaves is used to stop vomiting. The green tender leaves are eaten raw for the cure of dysentery. A decoction of the leaves is sometimes given with bitters as a febrifuge and the leaves have been claimed to be used with mint in the form of "chutney" to check vomiting. It has also been used as an anti-periodic and many a time the powdered dry leaf, mixed with honey and juice of betel nut, is recommended in the Ayurvedic system of medicine [4].

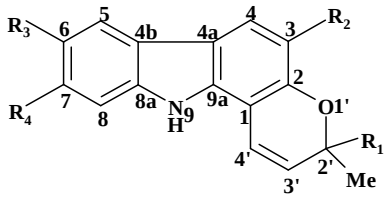
As extensive work has been carried out on *Murraya koenigii*, the more important and popular of the two Indian species, a comprehensive review has been made on this plant. An intense search of the literature has revealed that the stems, leaves, roots and seeds are potential sources of carbazole alkaloids of common and lesser known skeleta.

1. Pyrano Carbazole type: *Murraya koenigii* contains several alkaloids possessing the pyranocarbazole moiety (Figure 1). The compounds isolated have been given in Table 1.



Pyranocarbazole type alkaloid

Figure 1



Pyranocarbazole alkaloid (another type)

Figure 2

Representatives of another type of pyranocarbazole alkaloids (Figure 2) isolated from this species have been given in Table 2.

Table 1: Pyranocarbazole type alkaloids (Figure 1) isolated from the *M. koenigii*

No.	Compound	Mol. Formula & Physical State	Source	Substituents				Ref.
				R_1	R_2	R_3	R_4	
(i)	Koenimbine	$C_{19}H_{19}NO$ m.p. 194 ºC	Seeds, Leaves & Stem bark	Me	OMe	H	H	[5-7,8, 9,10,11]
(ii)	Murrayacine	$C_{18}H_{15}NO_2$ m.p. 244 ºC	Stem bark	CHO	H	H	H	[5,10,12]
(iii)	Girinimbine	$C_{18}H_{17}NO$ m.p. 174 ºC	Roots, Seeds & Stem bark	Me	H	H	H	[5,8-10,13,14]
(iv)	Koenimbidine or Koenidine or Koenigicine	$C_{20}H_{21}NO_3$ m.p. 224 ºC	Roots & Leaves	Me	OMe	OMe	H	[5,7,10,11, 15]
(v)	Koenine	$C_{18}H_{17}NO_2$ m.p. 250 ºC	Leaves	Me	OH	H	H	[7,15,16]
(vi)	Koenigine	$C_{19}H_{19}NO_3$ m.p. 183 ºC	Leaves	Me	OMe	OH	H	[7,15,17]
(vii)	Mukonicine	$C_{20}H_{21}NO_3$ m.p. 234 ºC	Leaves	Me	OMe	H	OMe	[18]

Table 2: Pyranocarbazole type alkaloids (another type) (Figure 2) isolated from this species

No.	Compound	Mol. Formula & Physical State	Source	Substituents				Ref.
				R_1	R_2	R_3	R_4	
(i)	Mahanimbine	$C_{23}H_{25}NO$ m.p. 94-95 ºC sp. rot. +52º ($CHCl_3$)	Roots, Leaves & Seeds	$(CH_2)_2CH=CMe_2$	Me	H	H	[5-10, 13,14, 19-23]
(ii)	Mahanine	$C_{23}H_{25}NO_2$ m.p. 100 ºC sp. rot. -24.4º ($CHCl_3$)	Leaves & Seeds	$(CH_2)_2CH=CMe_2$	Me	H	OH	[7-9,15, 20,21]
(iii)	Mahanimbinine	$C_{23}H_{27}NO_2$ m.p. 179 ºC	Seeds	$(CH_2)_3C(OH)Me_2$	H	H	H	[24]
(iv)	Murrayacinine	$C_{23}H_{23}NO_2$ m.p. 105 ºC	Leaves	$(CH_2)_2CH=CMe_2$	CHO	H	H	[14]
(v)	Isomahanimbine or Mahanimbicine	$C_{23}H_{25}NO$ m.p. 142 ºC sp. rot. +4º ($CHCl_3$)	Roots & Leaves	$(CH_2)_2CH=CMe_2$	H	Me	H	[5,7,10, 21]
(vi)	Mahanimboline	$C_{23}H_{25}NO$ m.p. 170-172ºC	Roots	$(CH_2)_2CH(OH)C(Me)=CH_2$	Me	H	H	[25]
(vii)	Isomahanine	$C_{23}H_{25}NO_2$ m.p. 184 ºC	Seeds	$(CH_2)_2CH=CMe_2$	H	Me	OH	[8,9]

Spectral analyses of pyranocarbazole alkaloids: The spectral analyses of some representative members of pyranocarbazole alkaloids have been discussed [7].

The NMR spectra ($CDCl_3$) of all the alkaloids indicated the presence of an aromatic methyl group (δ 2.2-2.3) and two *cis*-olefinic protons. The chemical shifts of the olefinic protons were similar to those of the chromenes suggesting that the alkaloids had a fused pyran ring (Table 3). The NMR spectra of the alkaloids further showed the presence of (i) one methoxy group in koenimbine and koenigine and two in koenidine (δ 6.8-6.9), (ii) one $–O-CMe_2$ group in koenimbine, koenine, koenigine and koenidine (δ 1.40-1.42) and (iii) one-O-C-Me group in mahanimbine, mahanine and isomahanimbine (δ 1.37-1.43).

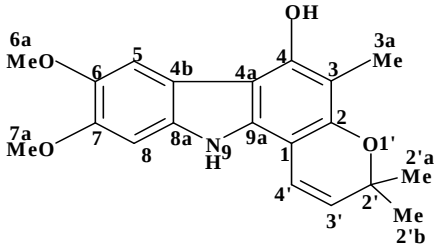
Table 3: Chemical shift (δ) of C-3' and C-4' protons in various alkaloids

Alkaloids	$C_{3'}$-H		$C_{4'}$-H	
	$CDCl_3$	DMSO	$CDCl_3$	DMSO
Koenimbine	5.63	5.75	6.55	6.88
Koenine	—	5.73	—	6.84
Koenigine	5.65	5.72	6.55	6.85
Koenidine	5.65	5.75	6.58	6.87
Mahanimbine	5.60	5.67	6.67	6.93
Mahanine	5.53	5.71	6.41	6.89
Isomahanimbine	5.43	5.56	6.37	6.87

In all the alkaloids, intense peaks corresponding to aromatisation of the pyran ring by the loss of (i) a methyl group in the case of koenine, koenigine, koenidine and koenimbine and (ii) a methyl group or C_6H_{11} side chain in the case of mahanine, isomahanimbine and mahanimbine in the mass spectra were obtained.

The side chain, $-C_6H_{11}$, present in mahanine, isomahanimbine and mahanimbine was shown to be a $–CH_2-CH_2-CH=CMe_2$ moiety since in the mass spectra there were fragments corresponding to the loss of $–CH_2-CH=CMe_2$ (M^+ - 69) and $–CH_2-CH_2-CH=CMe_2$ (M^+ - 83). The NMR spectra of these alkaloids also showed signals corresponding to $=CMe_2$ and $–CH_2-CH=C<$. Further, the C_6H_{11} side chain was identical in all the alkaloids as revealed from the NMR spectral analysis. In girinimbine, the characteristic peaks in the pyran ring appeared at δ 6.5 for C-4' proton and δ 5.5 for C-3' proton.

2. Pyranocarbazole alkaloid of special type: Till to-date, one pyranocarbazole alkaloid, Kurryam (Figure 3) has been isolated from the seeds of this species bearing a phenolic hydroxyl at C-4 [26].



Kurryam [26] ($C_{20}H_{21}NO_4$; m.p. 206°)

Figure 3

The presence of –OH and >NH groups were confirmed from the ^{1}H-NMR signals at δ 7.77 and δ 7.55 (two broad singlets, which disappeared on deuteration). The ^{1}H-NMR spectrum of the compound indicated the presence of two methoxy groups at δ 3.93 (3H, s, H-6a) and δ 3.98 (3H, s, H-7a). The spectrum also showed two peaks for the *gem*-dimethyl group at δ 1.61 and δ 1.48 in the pyran ring. The peak at δ 2.33 indicated the presence of one aromatic methyl group. The olefinic protons at H-3' and H-4' exhibited doublets at δ 5.68 (1H, d, *J* = 9.9 Hz, H-3') and δ 6.59 (1H, d, *J* = 9.9 Hz, H-4'), respectively, characteristic of the double bond in the pyran ring.

3. *N*-Substituted hexacyclic pyranocarbazole type: *Murraya koenigii* contained three alkaloids of this type (Figure 4). The compounds isolated from the roots, stems and leaves are given in Table 4.

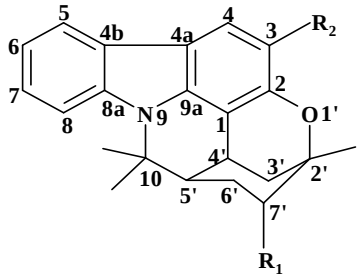


Figure 4: *N*-substituted hexacyclic pyranocarbazole type alkaloid

Table 4: *N*-Substituted hexacyclic pyranocarbazole alkaloids (Figure 4) isolated from *M. koenigii*

No.	Compound	Mol. Formula & Physical State	Source	Substituents		Ref.
				R_1	R_2	
(i)	Murrayazoline or Mahanimbidine or Curryangin	$C_{23}H_{25}NO$ m.p. 266 ºC Optically inactive	Leaves	H	Me	[12,13,22,23, 27,28]
(ii)	Murrayazolinol	$C_{23}H_{22}NO_2$ m.p. 290 ºC	Roots & Stem bark	OH	Me	[28]
(iii)	Isomurrayazoline	$C_{23}H_{25}NO$ m.p. 269-270 ºC	Stem bark	H	H	[29]

***Spectral data of N-Substituted hexacyclic pyranocarbazole moiety*:** Spectral data of mahanimbidine and murrayazolinol (considered as representative members of this skeleton) have been discussed [22,28].

The NMR spectrum ($CDCl_3$) of mahanimbidine showed the following signals: δ 1.26 (s) and δ 1.90 (s) for one *gem*-dimethyl group, δ 1.43 (3H, s) for –O-C-CH_3 group, δ 2.33 (s) for aromatic methyl group, δ 3.33 (b.m.) for benzylic methine proton and at δ 8.00-7.13 (m) for five aromatic protons.

The NMR spectrum of murrayazolinol showed the presence of a *gem*-dimethyl group (δ 1.93 and 1.50, 3H, s), a methyl on an oxygen-bearing tetrasubstituted carbon (δ 1.30, 3H), an aromatic methyl (δ 2.34, 3H, s), a benzylic proton (δ 3.33, 1H, br.) and the alcoholic hydrogen of a secondary alcohol (δ 3.8, dd, *J* = 7.2 Hz). The spectrum also showed signals for five aromatic

hydrogens of which the C-4 hydrogen appeared as a singlet at δ 7.50, the C-5 hydrogen as double doublet at δ 7.95 (*J* = 7.1 Hz) and the remaining three hydrogens as a complex multiplet in the region δ 7.15-7.40.

4. Cyclic pyranocarbazole type: *Murraya koenigii* contained three alkaloids possessing the pyranocarbazole moiety with a four membered cyclic ring (Figure 5, Table 5).

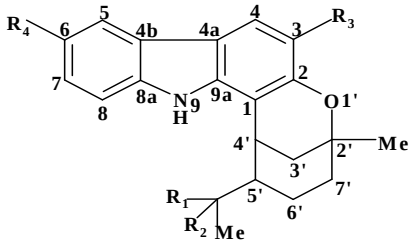


Figure 5: Cyclic pyranocarbazole type alkaloid

Table 5: Cyclic pyranocarbazole alkaloids (Figure 5) obtained from *M. koenigii*

No.	Compound	Mol. Formula & Physical State	Source	Substituents				Ref.
				R_1	R_2	R_3	R_4	
(i)	Cyclomahanimbine or Curryanine	$C_{22}H_{25}NO$ m.p. 146 ºC sp. rot. 0º ($CHCl_3$)	Leaves & Stem bark	$=CH_2$	—	Me	H	[10,22, 23]
(ii)	Murrayazolinine	$C_{23}H_{27}NO_2$ m.p. 184 ºC	Stem bark	Me	OH	Me	H	[28,30]
(iii)	Isomurrayazolinine	$C_{23}H_{25}NO$	Stem bark	OH	Me	H	Me	[28]

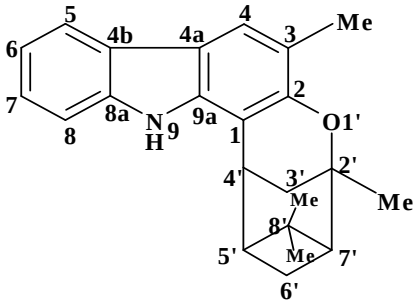
***Significant spectral data of the pentacyclic alkaloid moiety*:** Among these compounds, the spectral data of cyclomahanimbine, considered as a representative compound bearing the pentacyclic skeleton has been discussed [22].

The NMR spectrum in CCl_4 showed the following signals: δ 1.36 (6H, s), two methyl groups, one –O-C-CH_3 and the other =C-CH_3 both overlapping. The aromatic methyl group appeared at δ 2.33 (3H, s). One benzylic methine proton and 2 –C=CH_2 protons appeared at δ 3.11 and δ 4.72 respectively. One –NH proton showed a broad singlet at δ 7.55 and the single aromatic proton C-4 hydrogen was discernible at δ 7.67. The other aromatic protons at C-5 and C-7, C-8 appeared at δ 7.88 and in the region δ 7.43-7.00 (3 protons) respectively.

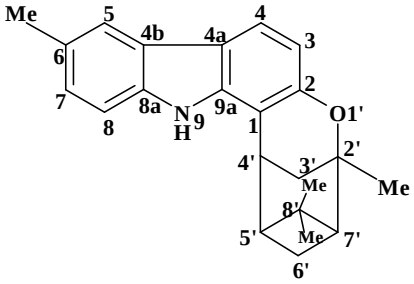
5. Bicyclic pyranocarbazole type: Till to-date, two alkaloids, bicyclomahanimbine and bicyclomahanimbicine having the bicyclic pyranocarbazole moiety (Figure 6) have been isolated from the leaves of this species.

The NMR spectrum ($CDCl_3$) of bicyclomahanimbine showed two three proton singlets each at δ 0.71 and δ 1.53 for the two *gem*-dimethyl group in the cyclobutane ring. A three proton singlet appeared at δ 1.43 for the methyl group in the pyran ring. The aromatic methyl and a benzylic

methine proton resonated at δ 2.36 and δ 3.26 respectively. One aromatic proton and one –NH proton appeared in the region δ 8.08-7.05 [22].



Bicyclomahanimbine [10,13,22,23]
$C_{23}H_{25}NO$
m.p.145º
Sp. rot. -1.23º ($CHCl_3$)

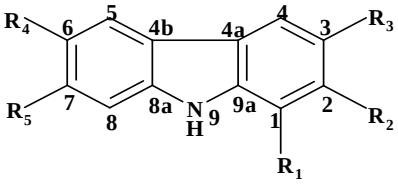


Bicyclomahanimbicine [10]
$C_{23}H_{25}NO$
m.p. 218º (decomp.)

Figure 6

The NMR spectrum ($CDCl_3$) of bicyclomahanimbicine [10] showed two three protons singlets each at δ 0.75 and at δ 1.53 for two *gem*-dimethyl groups in the cyclobutane ring. Two three protons singlets appeared at δ 1.43 and δ 2.51 for the pyran ring methyl group and aromatic methyl group respectively. A one proton doublet appeared at δ 6.80 (J = 8.0 Hz) and δ 7.76 (J = 8.0 Hz) for H-3 and H-4 protons respectively. A two hydrogen multiplet at δ 7.21 was assigned to the H-7 and H-8 protons. A broad singlet appeared at δ 7.31 for the –NH proton (disappeared after D_2O shake).

6. Carbazole type: Several carbazole alkaloids have been isolated from the different parts of this species. (Figure 7, Table 6).



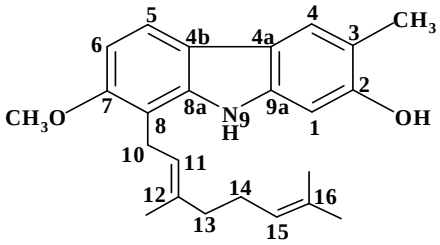
Carbazole type alkaloid
Figure 7

Table 6: Carbazole alkaloids (Figure 7) obtained from *M. koenigii*

No.	Compound	Mol. Formula & Physical State	Source	Substituents					Ref.
				R_1	R_2	R_3	R_4	R_5	
(i)	Mukoeic acid	$C_{14}H_{11}NO_3$ m.p. 242 ºC	Stem bark	OMe	H	CO_2H	H	H	[31]
(ii)	Murrayanine	$C_{14}H_{11}NO_2$ m.p. 168 ºC	Stem bark	OMe	H	CHO	H	H	[13,31-34]
(iii)	Mukonine	$C_{15}H_{13}NO_3$ m.p. 195 ºC	Stem bark	OMe	H	CO_2Me	H	H	[29]

(iv)	Mukonidine	$C_{14}H_{11}NO_3$ m.p. 245 ºC	Stem bark	H	OH	CO_2Me	H	H	[11]
(v)	Mahanimbinol	$C_{23}H_{27}NO$ m.p. 250 ºC	Stem bark	CH_2CH= C(Me) $(CH_2)CH$ =CMe_2	OH	Me	H	H	[13,14]
(vi)	Mukoline	$C_{14}H_{13}NO_2$ m.p. 115-120 ºC	Roots	OMe	H	H	CH_2OH	H	[32]
(vii)	Mukolidine	$C_{14}H_{13}NO_2$ m.p. 152-155 ºC	Roots	OMe	H	H	CHO	H	[32]
(viii)	3,6-dimethyl-1-isopentenyl carbazole	$C_{19}H_{21}N$ m.p. 168 ºC	Roots	CH=CHC Me_2	H	CH_3	CH_3	H	[35]
(ix)	Murrayanol	$C_{24}H_{29}NO_2$ m.p. 161 ºC	Leaves & Seeds	CH_2CH= C(Me) $(CH_2)_2CH$ =CMe_2	OH	H	CH_3	OCH_3	[9,20]
(x)	Girinimbilol	$C_{18}H_{19}NO$	Stem bark	CH_2CH= CMe_2	OH	Me	H	H	[14]
(xi)	Koenoline	$C_{14}H_{13}NO_2$ m.p. 130 ºC	Roots	OMe	H	CH_2OH	H	H	[36]
(xii)	Glycozoline	$C_{14}H_{13}NO$ m.p. 182-183 ºC	Roots	H	H	Me	OMe	H	[37]
(xiii)	3-methyl Carbazole	$C_{13}H_{11}N$ 204-206 ºC	Roots	H	H	Me	H	H	[37,38]
(xiv)	2-hydroxy-3-methyl carbazole	$C_{13}H_{11}NO$	Roots	H	OH	Me	H	H	[39]

Along with all the carbazole alkaloids mentioned, an interesting carbazole alkaloid, Euchrestine B, has been isolated from the leaves of *M. koenigii*. The structure of this compound has been shown in Figure 8.



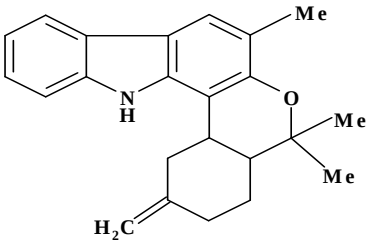
Euchrestine B [11]
$C_{24}H_{29}NO_2$
Figure 8

***Spectral data of the carbazole alkaloid moiety*:** The important members of this type of alkaloids are mukoline and mukolidine (Table 6). Spectral data of these compounds have been discussed [32].

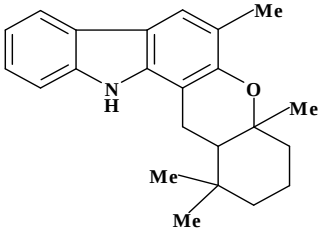
The NMR spectrum of mukoline (in $CDCl_3$) indicated the presence of NH-function at δ 8.22. The aromatic protons resonated at δ 7.0-7.9. The benzylic methylene protons were deshielded and the chemical shift appeared at δ 4.75. A hydroxyl proton and aromatic methoxyl protons were discernable at δ 4.45 and δ 3.90 respectively.

The NMR data of mukolidine showed the presence of an aldehyde proton at δ 10.8. One –NH proton appeared at δ 8.6 and the aromatic protons resonated at δ 8.15, δ 8.08 and in the region δ 7.3-7.6. The aromatic methoxy group was discernible at δ 4.05.

7. Pentacyclic pyranocarbazole type: Two pyranocarbazole alkaloids with five cyclic ring structures, viz. murrayazolidine and bicyclomahanimbiline, have been isolated from the stem bark of *M. koenigii* (Figure 9).



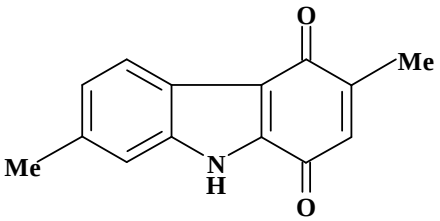
Murrayazolidine [9,40,41]
$C_{23}H_{25}NO$
m.p. 143º
sp. rot. +20º ($CHCl_3$)



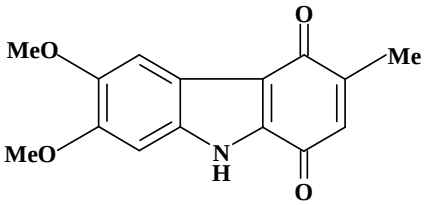
Bicyclomahanimbiline [42]
$C_{23}H_{27}NO$

Figure 9

8. Quinone type: Till todate, two carbazole alkaloids having the quinone moiety (Figure 10) have been obtained from the stem bark of this species.



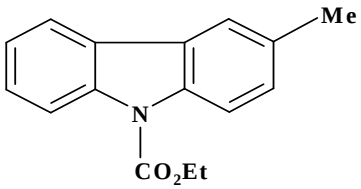
Koenigine-quinone A [16]
$C_{14}H_{11}NO_3$
m.p. 236-238º



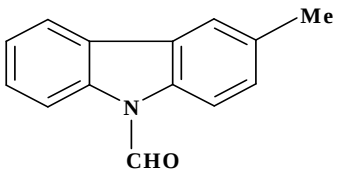
Koenigine-quinone B [16]
$C_{15}H_{13}NO_4$

Figure 10

9. *N*-Substituted carbazole alkaloid: Recently, two *N*-substituted carbazole alkaloids, i.e. 9-carbethoxy-3-methyl carbazole, and 9-formyl-3-methyl carbazole, were isolated from the roots of *M. koenigii*. These two metabolites displayed weak cytotosicity against both mouse melanoma B16 and adriamycin-resistant P 388 mouse leukemia cell lines [38] (Figure 11).



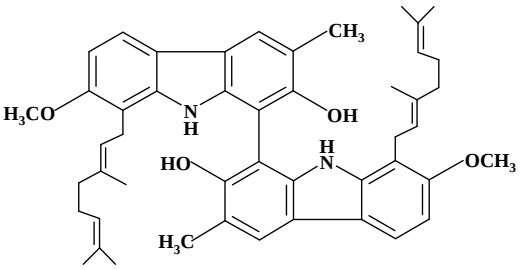
9-carbethoxy-3-methyl carbazole [38]
$C_{16}H_{15}NO_2$
m.p. 122-123º



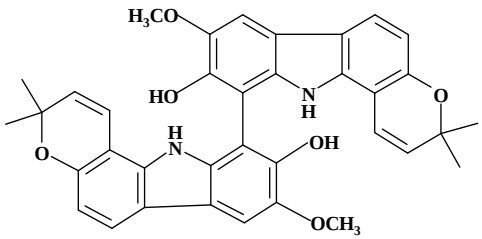
9-formyl-3-methyl carbazole [38]
$C_{14}H_{11}NO$
m.p. 58-60º

Figure 11

Another class of compounds i.e. the symmetrical dimers of the carbazole alkaloids, have also been isolated from the leaves of this species (Figure 12).



Bismurrayafoline E [21, 24]
$C_{48}H_{56}N_2O_4$

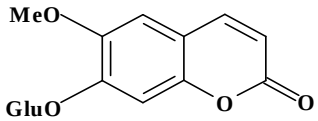


8,8″-Biskoenigine [17, 31]

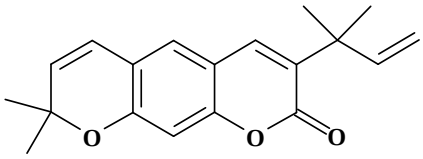
Figure 12

10. Coumarins: Besides alkaloids, coumarin derivatives have been found to be present in *M. koenigii*. The coumarin derivatives have been isolated from the stem bark of this species (Figure 13).

Glu = Glucopyranosyl



Scapolin [41]
$C_6H_{18}O_9$
m.p. 218º



3-(1,1-dimethylallyl) Xanthyletin [42]
$C_{19}H_{20}O_3$
m.p. 100º

Figure 13

The essential oils from the seeds, flowers and leaves of *Murraya koenigii* Spreng, were analysed by GC and GC/MS and revealed the presence of several different types of compounds in trace amounts. These are given in Table 7.

Table 7: Minor compounds isolated from *M. koenigii*.

No.	Compounds	References	No.	Compounds	References
1.	Sabinene	[43-46]	23.	Phellopterin	[52]
2.	*Trans*-*β*-caryophyllene	[43]	24.	Gosferol	[52]
3.	*α*-pinene	[43,44,46-48]	25.	Neobyakangelicol	[52]
4.	*β*-cubebene	[43,46]	26.	Byakangelicol	[52]
5.	*β*-gurjunene	[45,46,49]	27.	Byakangelicin	[52]
6.	*β*-caryophyllene	[45-50]	28.	Isogosferol	[52]
7.	*cis*- caryophyllene	[51]	29.	*β*-sitosterol	[52]
8.	Dipentene	[51]	30.	*β*-elemene	[45,46]
9.	*α*-eudesmol	[51]	31.	D-limonene	[45]
10.	Isocaryophyllene	[51]	32.	Camphene	[46]
11.	SS-elemene	[51]	33.	Limonene	[46]
12.	*α*-phellandrene	[46,47]	34.	*α*-selinene	[46]
13.	*β*- phellandrene	[44-48]	35.	*δ*-cadinene	[46]
14.	(E)-*β*-ocimene	[47,50]	36.	*β*-bisabolene	[46]
15.	*β*-pinene	[44-47]	37.	Caryophyllene epoxide	[46]
16.	Myrcene	[47]	38.	*α*-copaene	[46]
17.	*γ*-terpinene	[44,46,47]	39.	Humulene	[46]
18.	*α*-terpinene	[44]	40.	Selin-11-en-4α-ol	[46]
19.	Terpinen-4-ol	[44,48]	41.	*α*-cubebene	[46]
20.	Linalool	[45,50]	42.	*β*-thujene	[46]
21.	Xanthotoxin	[52]	43.	*ε*-murolene	[46]
22.	Isobyakangelicol	[52]	44.	*γ*-cadinene	[46]

11. Medicinal importance of *Murraya koenigii* Spreng: Curry leaf tree (*Murraya koenigii* L. Spreng, Rutaceae) is a plant which has various important uses in the traditional system of medicine in Eastern Asia [53]. Based on ethnomedicine, *Murraya koenigii* is used as a stimulant, antidysentric and for the management of diabetes Mellitus [54-56]. The methanol extracts were devoid of hypoglycemic activity. Some isolates of these extracts decreased insulin secretion when they were subjected to both in *vivo* and in *vitro* (insulin secretion from INS-1 cells) antidiabetic tests [54]. The methanolic extract of *M. koenigii* leaves was evaluated on human oral and cell mediated immune response to ovalbumin, phagocytic activity by carbon clearance test, nitric oxide (NO) release from murine peritoneal macrophages and cyclophosphamide induced myclosuppression [57]. Effect of the leaves of *M. koenigii* on carbohydrate metabolism has been studied using rats as experimental animals. It showed significant hypoglycemic action. There was increase in the concentration of hepatic glycogen [58].

Mahanimbine, murrayanol and mahanine are three carbazole alkaloids isolated from the acetone extract of the fresh leaves of *Murraya koenigii*. Of these three, murrayanol showed an IC_{50} of 109 μg/mL against hPGHS-1 and an IC_{50} of 218 μg/mL against hPGHS-2 in anti-inflammatory assays, while mahanimbine displayed antioxidant activity at 33.1 μg/mL. All these three carbazole alkaloids were mosquitocidal and antimicrobial and exhibited topoisomerase I and II inhibition activities [10].

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 (DPPH) [11].

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 [59].

Carbazole alkaloids isolated from the stems of *Murraya koenigii* (Rutaceae) have effects on the growth of the human leukemia cell line HL-60. Also the carbazole alkaloids, mahanine, pyrafoline-D and murrafoline-I showed significant cytotoxicity against HL-60 cells and induced the loss of mitochondrial membrane potential [60].

The bioassay guided fractionation of the *n*-hexane extract of the seeds of *Murraya koenigii* Spreng (Rutaceae) resulted in the isolation of three bioactive carbazole alkaloids, kurryam, koenimbine and koenine. The structures of the compounds were confirmed from their ^{1}H-, ^{13}C-, and 2D-NMR spectral data. Of the three compounds kurryam and koenimbine exhibited significant inhibitory activity against castor oil-induced diarrhoea and PGE_2-induced enterpooling in rats. The compounds also produced a significant reduction in gastro-intestinal motility in the charcoal meal test in Wister rats [61].

Conclusion

From the above discussion it can be inferred that *Murraya koenigii* is a rich source of biologically active carbazole alkaloids which would attract the attention of chemists and pharmacologists and play a significant role in future research in medical science.

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