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Review Article

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Gmelina arborea : Chemical constituents, pharmacological activities and applications

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Abstract

Gmelina arborea (*G. arborea*) is a bio-prospective plant belonging to family verbenaceae. It is widely used for its medicinal properties from ancient times. The present paper comprehensively reviewed the traditional uses, medicinal properties and chemical constituents isolated from *G. arborea* based on literature reported as well as critical analysis of the research. The present article is aimed to provide information on recent advances and new foundations and direction for further exploring *G. arborea* for its applications. Pharmacological research reviewed that *G. arborea* possess various medicinal properties and biological activities including antidiuretic, antidiarrhoeal, antipyretic, antianalgesic, antioxidant, antidiabetic, antihelmintic, antibacterial, antifungal, cardiopotective, insecticidal, antiulcer, gastro-protective, anticancer, antihyperlipidemic and immunomodulatory activity. It has been reported for its applications in treatment of bone fracture, hypertension and regeneration of β-cells. The main chemical constituents of *G. arborea* include lignans, iridoid glycoside, flavonoids, flavons, flavone glycoside and sterols. The present review provide all the references and beneficial directions to explore further application of *G. arborea.*

Keywords: *Gmelina arborea*, medicinal properties, antifungal activity, antibacterial activity, antioxidant activity and chemical constituents.

Introduction

Gmelina arborea is a deciduous tree locally known as Ghamhar. *G. arborea* belongs to family verbenaceae [1]. Its uses are highly immemorial because it has huge medicinal properties [2]. *G. arborea* is known to different name in different languages like Gomari in Assamese, Gamari, Gambar, Gumbar in Bengali, Shewan, Sivan in Gujarati, Gamhar, Khamara, Khumbhari, Sewan in Hindi, Kulimavu, Kumbuda, Kumulu in Kannada, Mara, Shivani in Kashmiri, Kumbil, Kumbulu, Kumilu, Kumiska, Pokki in Malayalam, Shivan, Siwan in Marathi and White teak in English. Originof *G. arborea* is Philipines and Malasiya and it is distributed all over India and South China, Bangladesh, Asian countries, Mayanmar, Thailand, Vietnam, Combodia, Indonesia and broadly in Africa and Latin American countries [3][4][5]. The best climatic condition for the cultivation of *G. arborea* is fertile soils, various rainfall regions. The tree has long maturation period so it is best plantation species for forest upgrading [6]. *G. arborea* planted in the presence of chlorophyll is outer bark of this plant. *G. arborea* wood is pale yellow to cream in colour and calorific value approximately 4400-4800 Kcal per kg [7]. The wood density of plant at age 8 years is 410 kg/m^2 [8]. The wood density and dimension of fibers are responsible to many structural, physical and chemical properties [9]. Flowering time is best in February to April and fruit is mature in month May to June. Plant is cultivated as garden and avenue tree. The plant also possess antimicrobial [10][11][12] and antifungal [13][14] properties and many more activities. Several chemical constituents have been isolated and characterized from *G. arborea*. The *G. arborea* plant extracts and isolated pure compounds have been used for the treatment of many kind of diseases.

Botanical description

The plant height of *G. arborea* is approximate 40 m and 140 cm in diameter [5]. The tree form is fair to good, with 6–9 m of branchless, often crooked trunk and a large, low-branched crown. The colour of bark is gray and bark is thin. The plant leaves structure is simple, opposite, less heart-shaped, length is 10-25 cm and width 5-18 cm. Flowers are brown in colour and arranged in penciled cymes 15-30 cm and it can appears after leaf-fall. Fruit size is drup 2.25 cm long and contains 1-4 seeds. One kg contains 700-1400 seeds [4] [21].

Ecological distribution

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The plant befalls at altitude 5 - 30 north and latitudes 70 -110 east and altitude range is 50-1300 meters [3]. *G. arborea* found in rain forest, dry deciduous forest and occurs from sea level up to 1200 m and rainfall 750-5000 mm. The best climatic temperature is 21ºC to 28ºC for the cultivation of *G. arborea*. The plant growing to deep, well drained, base rich soil and PH level maintain 5-8 [5][10].

Uses

Wood- Wood is yellowish in colour and useful for making paneling, planking, carriages, furniture and carpentry. The wood specific gravity is 0.42-0.64 and good calorific value approximately 4400-4800 Kcal per kg [7]. The wood is used for the carving images, canoes, match manufacture, packing cases and ornamental work. It is also used for manufacture of toys and picture frames. The timber is useful for paper making, molding, furniture, interior wood working, ship building, plywood etc [1]. *G. arboea* wood is used as row material for cellulose [15], firewood [16], polewood [17], particle board [18], veneer and some other structural uses [19].

Leaves and fruits- The leaves and fruits of *G. arborea* are used as a feed stuff in India. Its fruits and leaves have been reported to contain several chemical constituents having medicinal value [20].

Formulations and preparations

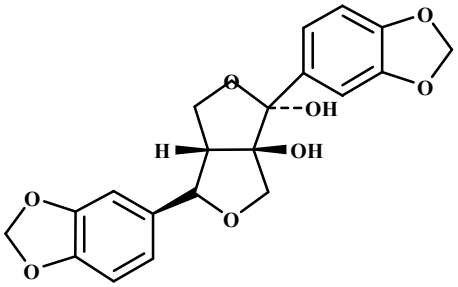
Several preparations from *G. arborea* have been reported in database on medicinal plants being used in Ayurveda for treatment of different disease. Dashamoolarishtam has been reported to show anti-inflammantory, anti-arthritic, digestive stimulant, anti-bacterial, anti-oxidant, anti-stress, anti-depressant properties and use of Dashamool arishtam to increase haemoglobin levels and helps in formation of red blood cells. Dashamoola haritaki has many properties like antipyretic, anti-oxidant, anti-inflammantory and analgesic. Dashamoolaghrita is used for the treatment of dry cough, cough with pain, sputum bronchitis and asthama. Dashamoolashatapalakaghrita is used for treatment of spleen disease and anemia. Arvindasava is used for the psychological problem of children, increases the body weight and strength. Drakshadikvathachurna is most useful in jaundice and other properties like antipyretic, anti-toxic, anti-emetic. Mritasanjivanisura is special ayurvedic medicine in liquid form. It has also contains self-generated alcohol. Mritasanjivanisura is used in the treatment of high fever and improves immunity, nourishes body tissues. Dashamoolakvatha churna is used for treatment of rheumatic complaints, asthma, cough, indigestion and general body weakness. Indukanta ghrita is used for the abdominal disease, chronic fever, bloating, weakness oral tiredness. Some other preparations of *G. arborea* are Shriparnyadi kvatha, Shriparni taila, Brihatpanchamoolyadi kvatha, Kashmarya kvatha, Kashmaryadisheeta kashya, Mooshakadya taila, Vayuchchhayasurendra taila, Dhanvantara ghrita [22].

Chemical constituents

Several chemical constituents isolated from *G. aborea* have been reported in literature. Nutritional phytoconstituents of *G. aborea* leaves have been analyzed by Offor, 2014. Bark of *G. arborea* has been reported to possess flavonoids, saponins, terpenoids and cardiac glycosides [90]. The concentration of phytoconstituents has been reported as follows: tannins- 0.06±0.00 mg, saponins- 3.85±0.07 mg, glycosides- 1.77±0.06 mg, flavonoids- 0.06±0.01 mg, alkaloids- 0.06±0.00 mg, phenols- 0.32±0.01 mg, steroids- 0.09±0.00 mg (mg/100gm). Proximate analysis (%) of the leaves revealed the percentage of moisture, fat, ash, crude fibre, protein, carbohydrate to be 12.35±0.52, 0.79±0.02, 4.55±0.49, 15.05±0.07, 20.05±0.07 and 47.21±1.04 respectively [23].

Lignans

Anjaneyulu et al. have reported the presence of lignin 2a, 6e-dipiperonyl-1e-2e-dihydroxy-3, 7-dioxabicyclo-[3, 3, 0]-octane. It is accompanied by 2-O-methyl ether and 2-O-ethyl ether and its 2-epimer, isoarboreol (1). The compound gmelanone (2) is another substance reported to be present in *G. aborea.* It has been derived from 3, 6-dioxabicyclo [3, 2, 1] octane [24], the heartwood of *G. aborea* has contain 6"-bromo isoarboreol, 4-hydroxysesamin, 4, 8-dihydroxysesamin, 1, 4-dihydroxysesamin (gummadiol) (3), piperonyl 3-hydroxymethyl-4-(-hydroxyl-3, 4-methylenedioxybenzyl) 4-hydroxytetrahydrofuran, and the 4-O-glucoside of 4-epigummadiol. It has enhanced the germination growth of *Aegilops ovate* [25]. Gummadiol 1, 4-dihydroxy-2, 6-dipiperonyl 3, 7-dioxabicyclo [3, 3, 0]octane is the first dihydroxylignans isolated from *G. aborea* [26]. keto-lignansarborone (4), arborone diacetate (5), 7-oxo-dihydro gmelinol (6), 7-oxo-dihydrogmelinol acetate (7), arboreal (8) [27][28] and some other lignans like (+)-7′*O*-ethyl arboreal (9), (+)-paulownin (10), (+)-gmelinol (11), (+)-epieudesmin (12) are reported to be present in heartwood of *G. arborea* [29]. Gribble has reported organobromine (13) from *G. arborea* [30]. Krishna et al. 1977 has isolated monobromo derivative of isoarboreol, is a bromine containing lignan from *G. arborea* [31]. [Figure-1]



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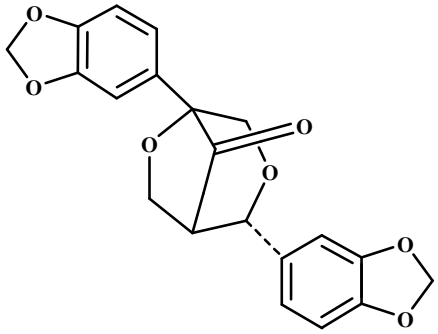

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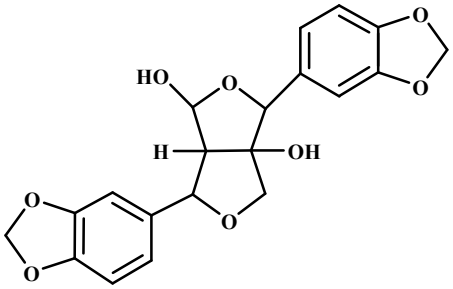

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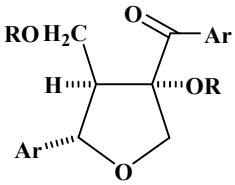
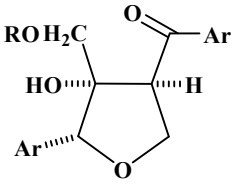


(A)



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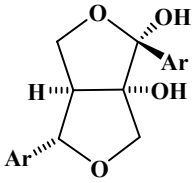
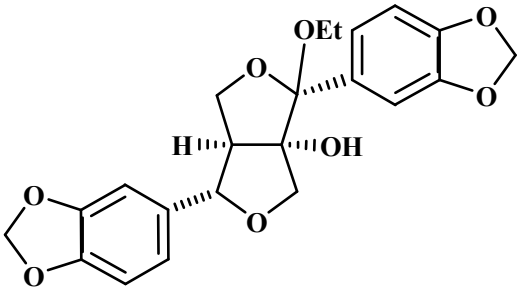


(C)

A-(4) Ar = piperonyl
R = H
A-(5) Ar = piperonyl
R = Ac

B-(6) Ar = veratryl
R = H
B-(7) Ar = veratryl
R = Ac

C-(8) Ar = piperonyl



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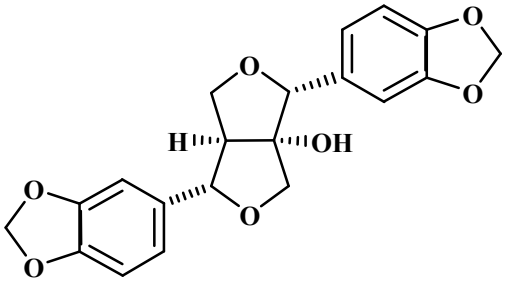

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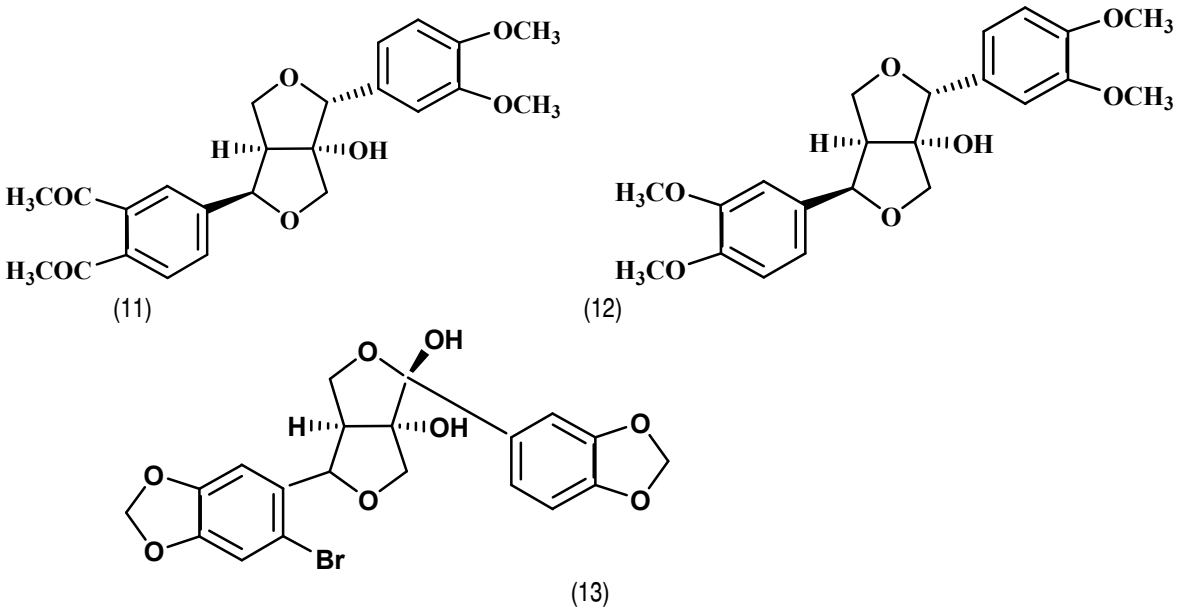
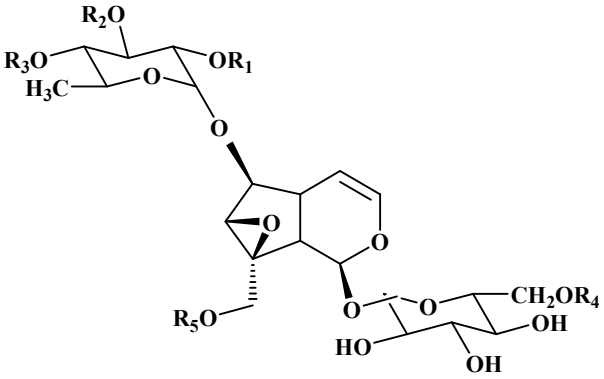
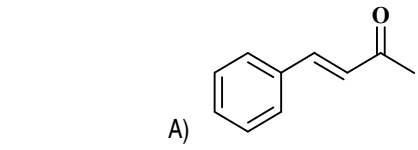


Figure 1:- Structure (1-13) of Lignans present in plant *G. arborea.*

Iridoid glycosides

6-O-(2,3-dibenzoyl)-α-L-rhamnopyranosylcatalpol has been reported to be present in the aerial part of plant [32]. *G. aborea* is known to possess gmelinosides(14) and acylated iridoid glycosides. Leaves of *G. aborea* have been reported to contain 10-O-trans-cinnamoyl-6-O- -L-rhamnopyranosylcatalpol(15), 10-O-trans-cinnamoyl-6-O-(2",3"-di-O-acetyl)- -L-rhamnopyranosylcatalpol (16), 10-O-trans-p-coumaroyl-6-O- -L-rhamnopyranosylcatalpol (17), 10-O-trans-caffeoyl-6-O- -L rhamnopyranosylcatalpol(18), 10-O-trans-feruloyl-6-O-(2",4"-di-O-acetyl)- -L-rhamnopyranosylcatalpol (19), 10-O-p-hydroxbenzoyl-6-O-(6'-O-acetyl)- -L-rhamnopyranosylcatalpol(20), 6-O-(2",3"-O-di-trans-feruloyl)- -L-rhamnopyranosylcatalpol(21), 6-O-(4"-O-acetyl-2",3"-O-di-trans-feruloyl)- -L-rhamnopyranosylcatalpol(22), 6-O-(2",4"-O-di-trans-p-coumaroyl)- -L-rhamnopyranosylcatalpol(23), 6-O-(2",4"-O-di-trans-p-coumaroyl)-R-L-rhamnopyranosylcatalpol(24), 6-O-(3",4"-O-di-benzoyl)- -L-rhamnopyranosylcatalpol(25), 6-O-(3"-O-acetyl-4"-O-trans-cinnamoyl)- -L-rhamnopyranosylcatalpol(26), 6-O-(3"-trans-feruloyl)-α-L-rhamnopyranosylcatalpol(27), 6-O-(2"-O-acetyl-3",4"-O-di-trans-cinnamoyl)-α-L-rhamnopyranosylcatalpol] (28) and martynoside [33]. Iridiod glycosides namely 6-O-(3"-O-benzoyl)-α-L-rhamnopyranosylcatalpol (29), 6-O-(3"-O-trans-cinnamoyl)-α-L-rhamnopyranosylcatalpol (30), 6-O-(3"-O-cis-cinnamoyl)-α-L-rhamnopyranosylcatalpol (31), 6-O-(3",4"-O-dibenzoyl)-α-L rhamnopyranosyl catalpolheptaacetate (32), 6-O-(3"-O-trans-cinnamoyl)-α-L-rhamnopyranosylcatalpol heptaacetate (33), 6-O-(3"-O-cis-cinnamoyl)-α-L-rhamnopyranosylcatalpol heptaacetate (34) were also isolated from leaves of *G. aborea* [34]. Iridoid glycosides namely 6-O-α-L-(4"-O-trans-cinnamoyl) rhamnopyranosylcatalpol (37), 6-O-α-L-(2",3"-di-O-trans-cinnamoyl)rhamnopyranosylcatalpol (39), 6-O-α-L-(2"-O-trans-cinnamoyl) rhamnopyranosylcatalpol (verbaspinoside) (40), 3-O-trans-cinnamoyl-α-L-rhamnopyranose (44), 2-O-trans-cinnamoyl-α-L-rhamnopyranose (45) are shown activity against cytotoxicity on liver. 6-O-α-L-(2"-O-transcinnamoyl-3-O-isovaleryl) rhamnopyranosylcatalpol (35), 6-O-α-L-(4"-O-trans-cinnamoyl) rhamnopyranosylcatalpol (36), 6-O-α-L-(3",4"-di-O-trans-cinnamoyl) rhamnopyranosylcatalpol (38), 6-O-α-L-(3"-O-trans-p-methoxycinnamoyl) rhamnopyranosylcatalpol (41), 6-O-α-L-(2"-O-trans-p-coumaroyl) rhamnopyranosylcatalpol (42) have been reported to possess hepatoprotective activity [35]. Some other iridoid glycosides are 6-O-α-L-(3"-O-trans-cinnamoyl) rhamnopyranosylcatalpol (43), 2-O-cis-cinnamoyl-α-L-rhamnopyranose (46), 1-O-transcinnamoyl-α-L-rhamnopyranose (47), 3-O-trans-p-methoxycinnamoyl-α-L-rhamnopyranose (48) have been isolated from flowers of this plant [35]. Verbascoside (49) isolated from the flowers and roots of *G. aborea* has been reported to possess both the activities cytotoxicity on liver and hepatoprotective activity [33],[35],[36].[Figure-2]





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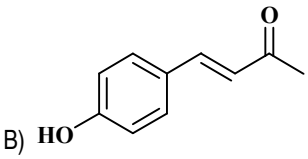

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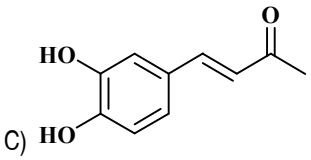

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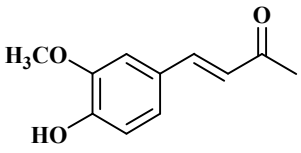

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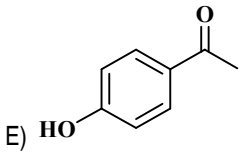

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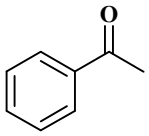
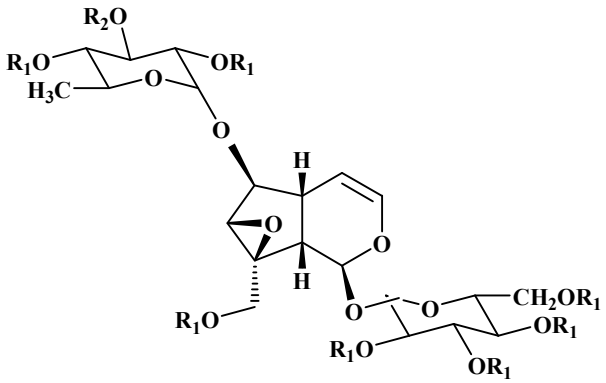


F)

	R_1	R_2	R_3	R_4	R_5
(14)	H	H	H	H	H
(15)	H	H	H	H	A
(16)	Ac	Ac	H	H	A
(17)	H	H	H	H	B
(18)	H	H	H	H	C
(19)	Ac	H	Ac	H	D
(20)	H	H	H	Ac	E
(21)	D	D	H	H	H

	R_1	R_2	R_3	R_4	R_5
(22)	D	D	Ac	H	H
(23)	B	H	B	H	H
(24)	F	H	F	H	H
(25)	H	F	F	H	H
(26)	H	Ac	A	H	H
(27)	H	D	H	H	H
(28)	Ac	A	A	H	H



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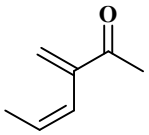

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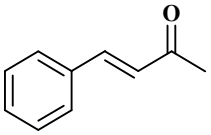

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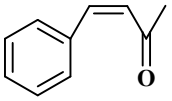
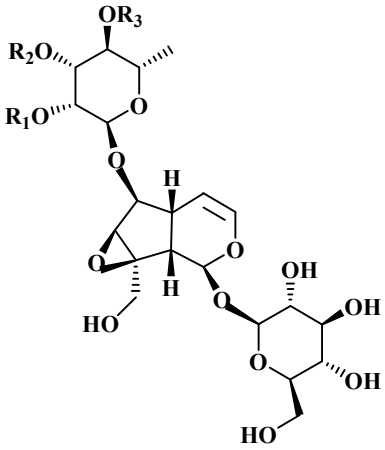
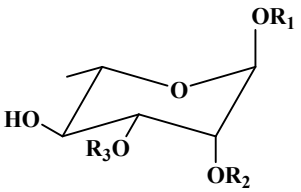


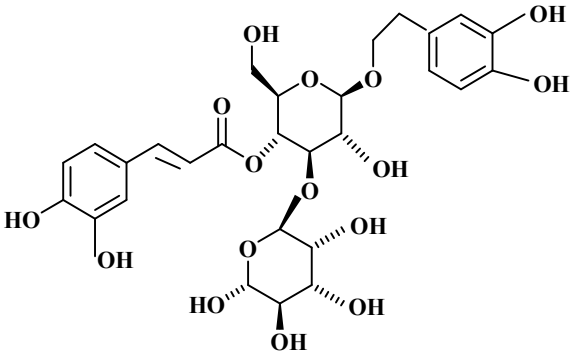
	R_1	R_2
(29)	H	A
(30)	H	B
(31)	H	C
(32)	Ac	A
(33)	Ac	B
(34)	Ac	C



	R_1	R_2	R_3
(35)	trans-cinnamoyl	Isovaleryl	H
(36)	trans-p-hydroxycinnamnoyl	trans-p-hydroxycinnamnoyl	H
(37)	H	H	trans-cinnamoly
(38)	H	trans-cinnamoly	trans-cinnamoly
(39)	trans-cinnamoly	trans-cinnamoly	H
(40)	trans-cinnamoly	H	H
(41)	H	trans-p-methoxycinnamnoyl	H
(42)	trans-p-hydroxycinnamnoyl	H	H
(43)	H	trans-cinnamoly	H



	R_1	R_2	R_3
(44)	H	trans-cinnamoly	H
(45)	H	H	trans-cinnamoly
(46)	H	cis-cinnamoly	H
(47)	trans-cinnamoly	H	H
(48)	H	H	trans-p-methoxycinnamnoyl

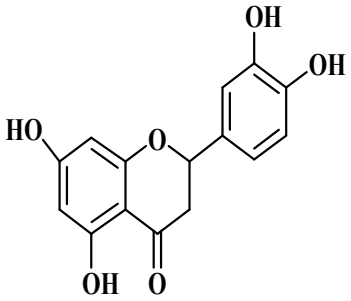


(49)

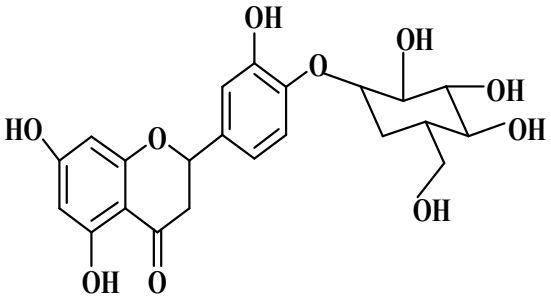
Figure 2:- Structure (14-49) of Iridoid glycosides present in plant *G. arborea*.

Flavonoids

Luteolin (50), a flavonoid isolated from leaves of *G. arborea* has been reported to reduce production of proinflammatory mediators in LPS-stimulated macrophages, fibroblasts, and intestinal epithelial cells [37][38][39]. Flavonoids luteolin-4'-O-β-D-$^4C_1$–galactoside (51), kaempferol (52), quercetin-13-O -β-D-$^4C_1$-glucopyranoside (isoquercitrin) (53), quercetin-3-O -$^4C_1$-L -rhamnopyranosyl-(1,6)-14-O -β-D-$^4C_1$-glucopyranoside (rutin) (54), luteolin-7-O-β-D-$^4C_1$-galactoside (55), quercetin-3-O-α-$^4C_1$-L-rhamnopyranosyl-(1,6)-β-$^4C_1$-D-galactopyranoside (quercetin-3-O-robinobioside) (56) have been isolated from 90% methanol extract of leaves and their antioxidant activity has also been evaluated via DPPH and phosphomolybdenum assays, while their cytotoxic activity has been reported towards liver-carcinoma cell line (HepG-2) via Sulphorhodamine-B assay [39]. Quercetin is a natural polyphenolic flavonoid and the presence of quercetin has increases brain and muscle mitochondrial biogenesis and exercise tolerance [40]. Olatunji, 1999 has reported Furanoresorcinol to be present in heartwood of *G. arborea* [41]. [Figure-3]



(50)



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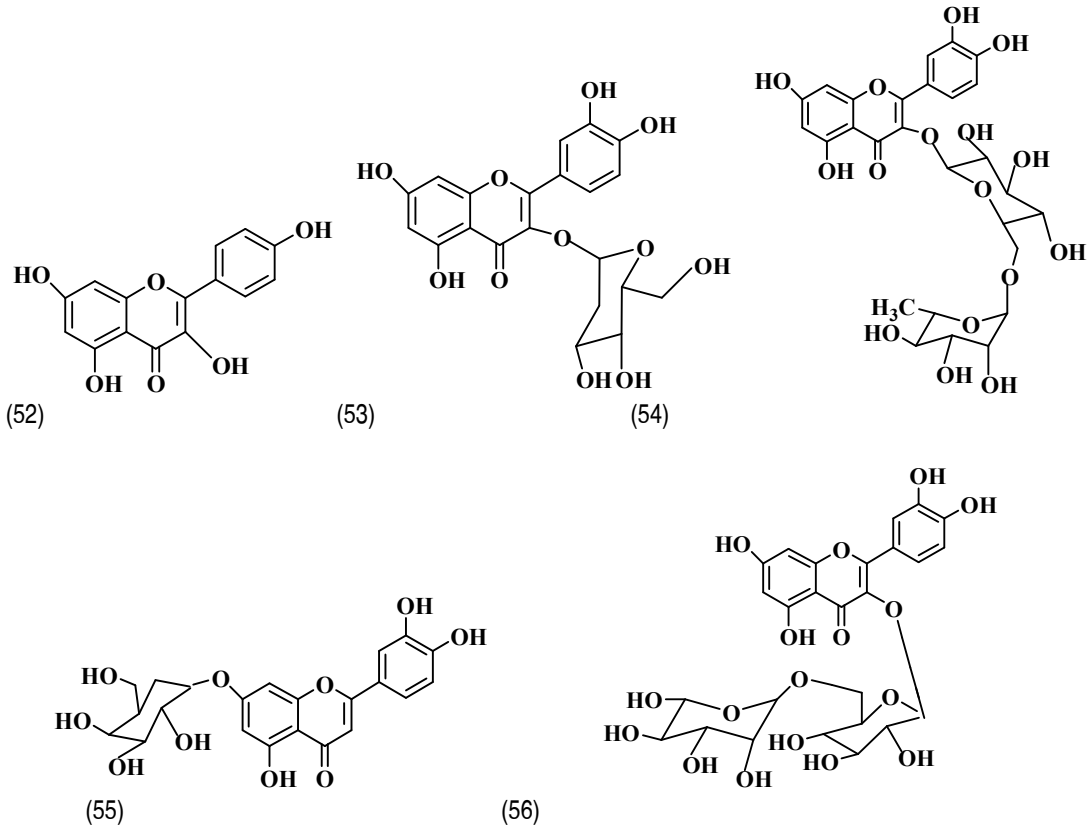
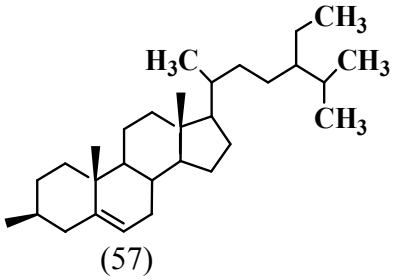


Figure 3:- Structure (50-56) of Flavonoids present in plant *G. arborea.*

Flavons, Flavone glycosides and Sterols

Sitosterol (57), quercetagetin, kaempferol (58), apigenin are the flavons reported to be present in roots of the plant andsome flavone glycoside like kaempferol-3-rutinoside, apigenin-7-rutinoside, apigenin-7-glucuronide, luteolin-7-Glucuronide [42], Coumarin glycosides are also reported to be present in the root of *G. arborea* [43]. Vidya et al. 2007 have also reported the quantification of apigenin in dried root powder from *G. arborea* by HPTLC method [44]. The non saponifiable fraction from the *G. arborea* wood has been reported to contain C18-C30 wax alcohols with C28 and C30 predominating (33.1 and 14.7%, resp.), sterols like- β-sitosterol, stigmasterol (59), stigmastanol, campesterol(60), α-2-sitosterol and triterpene alcohols (betulinol, a $C_{30}H_{50}O$ and others). Among the wax alcohols were small amounts of odd-numbered C chain representatives (C27 and C29). The saponifiables were fatty acids, with oleic and linoleic dominating and with a relative high amount of saturated fatty acids [45]. Adeyeye et al. 1991 has also reported fatty acid compounds namely lauric, myristic, palmitic, stearic, oleic, linoleic,linolenic, and arachidic acids from the *G. arborea* [46].[Figure-4]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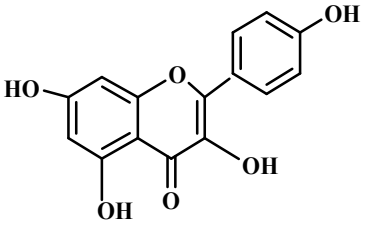
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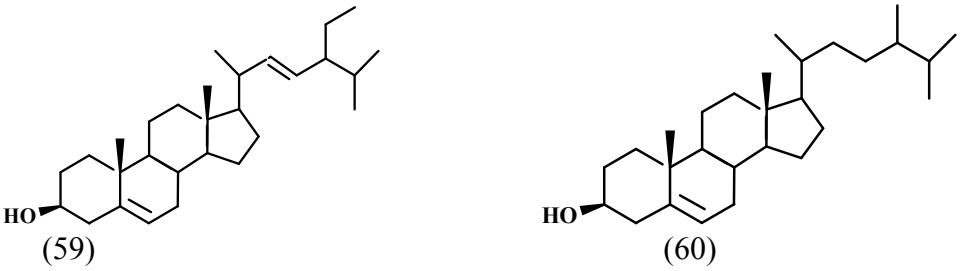
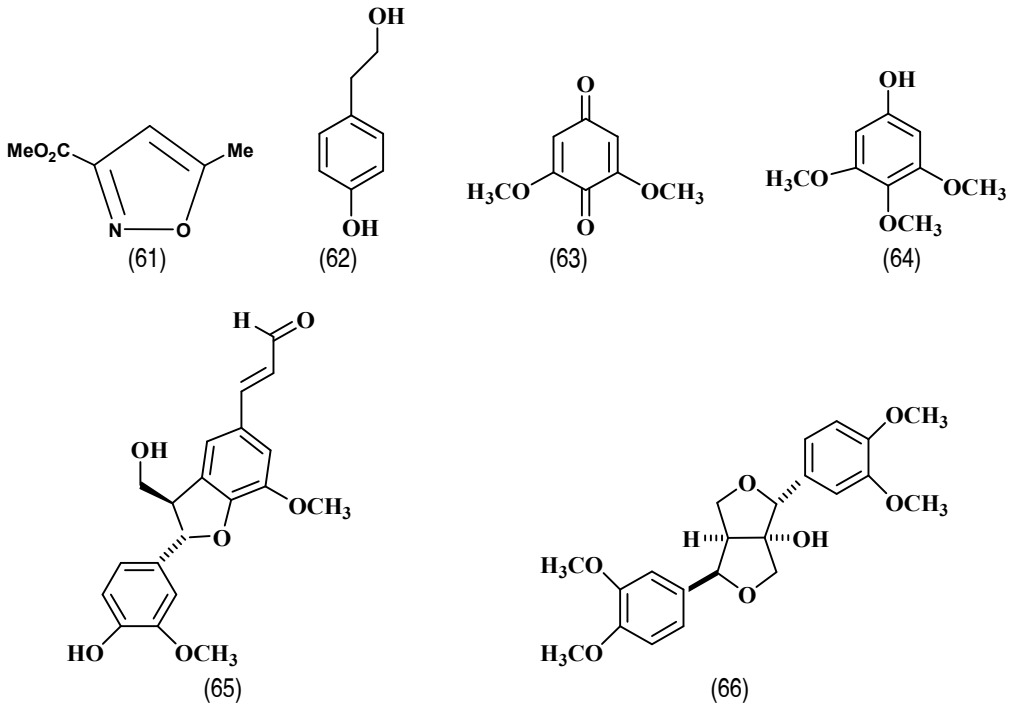
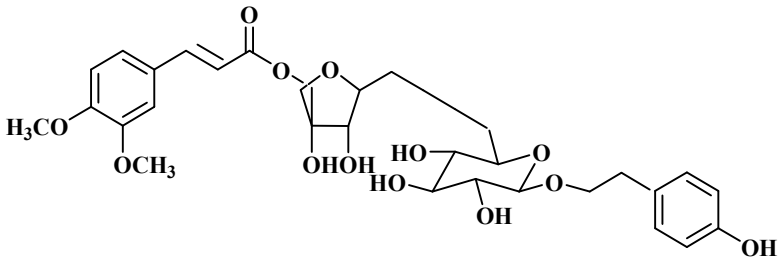


Figure 4:- Structure (57-60) of Flavons, Flavone glycosides and Sterols present in *G. arborea.*

Other compounds

G. arborea has been reported to contain preminazole (61) an anti-inflammatory isoxazole alkaloid [47][48]. The fractionation of the acetone extract of bark with *n*-hexane, diethyl ether and ethyl acetate and subsequent chromatographic separation of the fractions led to the isolation of four compounds. The diethyl ether-soluble fraction yielded tyrosol [2-(4-hydroxyphenyl)ethanol] (62), 2,6-dimethoxy-p-benzoquinone (63), 3,4,5-trimethoxyphenol (64), phenylethanoid glycoside, balanophonin (65), gmelinol (66), phydroxyphenylethyl [5'aEuro-(3)-O-(3,4-dimethoxycinnamoyl)-β-d-apiofuranosyl(1,6)]-ß-d-glucopyranoside (67) these compounds have been reported to possess antioxidant activity [49]. The four alkyl and one carbonyl resorcinol are reported to be present in the benzene extract of *G. arborea.* These compounds have been isolated by column chromatography and their structures were elucidated by chemical analysis and IR, NMR, and mass spectroscopy [50]. The light petroleum ether extract of the roots of plant contains hentriacontanol-1, a sesquiterpene, ceryl alcohol, β -sitosterol and octacosanol and aqueous extract of the roots contain gmelinol [51]. The leaves have also been reported to contain our crystalline constituents such as apigenin, luteolin, quercetin, hentriacontanol and *β*-sitosterol [52]. The roots of plant contain a long chain ester namely cluytylferulate [53].[Figure-5]





(67)

Figure 5:- Structure (61-67) of some other compound present in *G. arborea.*

Seed oils

Basumathy et al. 2012, prepared biodiesel from seeds oil of *G. arborea*. The main constituents of biodiesel prepared from *G. arborea* consists of methyl palmitate(15.09%), methyl oleate(44.88 %), methyl stearate(11.16 %), methyl gondoate(15.95%), methyl arachidate(4.21%) methyl behenate(8.67%) [54]. The chemical constituents of the fruit oil were examined with the help of capillary gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS). The fruit oil of *G. arborea* has been reported to possess (Z)-3-hexenol (17.9%), 1-octen-3-ol (8.4%) and hexanol (6.1%) among the aliphatic alcohols; heptacosane (5.6%), pentacosane (3.8%) and 1-pentacosene (3.2%) among the hydrocarbons and aldehyde namely nonanal (8.7%), (E)-2-decenal (3.0%) [55].

Medicinal use of *G. arborea*

Anti-diuretic activity

The methanolic extract of *G. arborea* exerts its diuretic activity due to synergistic action of the [$HCO3^-$ / Cl^-], [HCO3+/ H+] exchangers and the [N+/H+] antiporter by inhibiting tubular reabsorption and accompanying anions to cause dieresis [56].

Anti-diarrhoeal

The stem bark methanolic extract of *G. arborea* is reported to be used for stomach and urinary disorders. It acts as a laxative. Its decoction is used for looseningphlegm, appetite stimulant and in liver disorders [57].

Anti-pyretic, Analgesic activity and Toxicity

The stem bark extracts of *G. arborea* has been found to reduce hyperthermia and its effect is comparable to that of the standard anti-pyretic drug. The analgesic activity of *G. arborea* is found to be more significant as it predominantly inhibit the pain mechanism [58][59][60].

The alcoholic extract fractionated with different solvents like petroleum ether, chloroform, ethyl acetate, and n-butanol of *G. arborea* stem bark has been reported to toxicity and analgesic activity (as a dose 2000 mg/kg) in female Swiss albino mice using the OECD guidelines [61][62][63].

Anti-oxidant activity

In vitro-studies on bark and fruit extracts have shown anti-oxidant activities and protected liver slice culture cells by alleviating oxidative stress induce damage to liver cells. Flavonoids extracted from the aerial parts of *G. arborea* have shown good anti-oxidant property and good stability [39][49][64][65][66][67][68].

Anti-diabetic activity

The ethanolic extract of the plant has been reported to possess significant anti-diabetic activity; it increases blood GSH level reinforcing the role of GSH as free radical scavenger and in repair of the free radical caused biological damage. Aqueous extracts from the heart wood bark of the plant *G. arborea* has been reported to exhibit anti-diabetic activity in Streptozotacin (STZ) induced diabetic rats [69][70][71][72][73].

Anti-helminthic activity

The alcoholic and aqueous leaf have exhibited anti-helminthic activity by increasing chloride ion conduction of worm muscle membrane producing hyperpolarisation and reduces excitability that leads to muscle relaxation and flaccid paralysis [74][75].

Anti-bacterial activity

The crude leaf and stem bark extracts contains bioactive compounds such as alkaloids, saponins, carbohydrates, phenolics, anthraquinone and tannins. Due to the presence of these bioactive compounds the plant has been reported to possess significant antimicrobial activities against gram positive and gram negative organisms, *E. coli, K. pneumonia, P. dysentria, S. typhiaand P. mirabilis* [10][11][12].

Anti-fungal activity

Some constituents like 7′O-ethyl arboreol, paulownin, gmelinol, epieudesmin and β-sitosterol have been reported to exhibit antifungal activity against *Trametes versicolor* and *Fomitopsis palustris.* The root extract of *G. arborea* have been reported to inhibit the growth of *Aspergillus niger, Penicillium notatum* and *Candida albicans* [11][12][13][14].

Cardio-protective activity

The ethanolic extract of *G. arborea* has shown potential protective effect against doxorubicin induced cardiac toxicity by increasing cardiac maker's activities in plasma [76].

Insecticidal activity

The heartwood of *G. arborea* is a good source of insecticidal compounds. The aqueous extracts of fresh fruits, leaves and bark exhibit insecticidal property against legume pod borer and pod sucking bug [77].

Anti-ulcer activity

The hydroalcoholic extracts of leaf (286mg/kg and 667mg/kg) has been reported to possess activity against gastric ulcers. The extract was evaluated by using models aspirin induced ulcer, pylorus ligation induced ulcers, ethanol induced ulcers and cold restrains stress induced ulcers [78].

Gastro protective effect

Preclinical studies have been reported that hydroalcoholic extract of *G. arborea* showed significant gastro protection in rat model. The gastro protective activity of the test substance was evaluated by using ethanol induced gastric lesions model [79].

Anti-cancer activity

The hydroacetonic crude leaf extract contains phenolic constituents like flavonoids (75.50%), hydroxyl cinnamic acid derivatives (24.49%). It has been reported to exhibit anticancer potential against 6 cancerous cell lines. The cytotoxicity indicate that the hydroacetonic crude extract shows a good anticancer activity against C6 glioma and HL-60 cells [80][81].

Anti-hyperlipidemic effect

The ethanolic leaf extract of *G. arborea* (as a dose of 150 mg/kg of body weight) has been reported to exhibit significant hypoglycemic activity in animal models when compared with a standard antidiabetic drug Glibenclamide [82].

Aellochemical effect

G. arborea has been reported to affect the germination of red gram, green gram, black gram, and chickpea in terms of the levels of some important germination enzymes like acid phosphatase, catalase, peroxidase, and amylase [83].

Immunomodulatory activity

The ethanolic extract of the bark exhibit to reduce the hyperthelmia at a dose of 420 mg/kg body weight 1 hr after administration and it works as the standard anti-pyratic drug paracetamol at a dose of 50 mg/kg body weight. Whereas chloroform and benzene extract reduced 3h after their administration but have mild effect [84].

Treatment of bone fracture

Upadhya et al., 2012 have reported that *G. arborea* has the highest value (0.27) to use the bone strengthening, pain relieving, inflammation reduction and speedy recovery [85].

Wound healing activity

G. arborea is a traditional medicine the ethanolic extract of dried powder of leaves at dose level of 200 mg/kg has shown a good wound healing activity [86].

Treatment of hypertension

Lawson et al. have reported aqueous extract (500mg/kg/day) of *G. arborea* for treatment of hypertension to wistar rats model [87].

Used for β-cell regeneration

The stem bark extract (1.00g/kg) of plant *G. arborea* has been used for regeneration of β-cells of the pancreas in diabetic rats and serum lipid parameters are reported to get improved in *G. arborea* extract treated to diabetic rats [88].

Environmental application

One of the major issue of the concern of whole world today is increasing level of CO_2 in the atmosphere of earth and climate change due to origin level of CO_2. A study carried by Rasineni et al. (2011) indicates that *G. arborea* could accumulate significant biomass and escapaccimatory down regulation of photosynthesis due to high source-sink capacity even with and increase of 100 μ mol mol^{-1} CO_2 hence this plant species can be used to grown to protect environment against increasing concentrate of CO_2 [89].

Conclusion

The knowledge about *Gmelina arborea* is growing rapidly during recent few years but there are still significant gaps in the completeness of our understanding of its medicinal properties, biological activities and role played by each of chemical constituent isolated from different parts of this plant. It is still not investigated which of the chemical constituent determined its biological activities and medicinal application in Ayurvedic and traditional medicinal systems. Ayurvedic and herbal medicines are gaining popularity in the world due to adverse side effects of their synthetic counter parts. So it is required to ascertain production and supply of high quality herbal drugs to cure various health problems *G. arborea* is one of the potential medicinal plants being used in Ayurvedic and herbal medicinal system in India, African countries and Sri Lanka. Available knowledge of its medicinal properties and its application in ancient medicinal system of different countries does not fit into the requirements of evidence based medicines. Studies on correlation of biological activity and medicinal properties with chemical constituents have not been carried out systematically. Only scanty information on correlation of antifungal activity and 7′O-ethyl arboreol, paulownin, gmelinol, epieudesmin and β-sitosterol is available in literature. No reports are available on correlation of therapeutic applications for life style related diseases and chemical constituents.

Alkaloids, flavonoids, lignans, tannins, Iridioid glycoside and saponins were found to be present in this plant. The phenolic compounds such as flavonoids, tannins etc. are potential antioxidant and antioxidant activity of these compounds is due to their ability to scavenge free radicals. Phenolic compounds act as antimutagens and anticarcinogens and antimicrobial agents. The growth of many fungal and bacterial pathogens is inhibited by tannins. The tannins have been shown analgesic and anti-inflammatory activities. Saponins present in plants have been suggested as anti-carcnogens. Lignans and iridoid glycosides have been shown good anti-inflammatory activity. The presence of most of the chemical constituents is found to be encouraging and indicates the therapeutic potential of the species.

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Contribution of Authors

Dr Charu Arora has done literature survey and has written the article. Ms Vinita Tamrakar has searched the literature and draw structure of chemical constituents.

Conflict of interest

The authors declare that they have no conflict of interest.

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