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Bioactive Compound Studies of *Lawsonia inermis* L. (Henna) –Its Ethnomedicinal and Pharmacological Applications: A Review

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ABSTRACT

Plants play a wide role in our ecosystem due to their enormous medicinal properties and presence of diversified chemical constituents that are known to be highly beneficial to mankind to a large extent. The current review focusses on the detailed description, phytochemistry, bioactive components, ethnobotanical survey and the important pharmacological applications of the medicinal plant Lawsonia inermis L.It is commonly referred to as "Henna or Mehndi" and is a widely used plantknown for its coloring property and medicinal applications. It has wide distribution in both tropical as well as subtropical regions and has been extensively utilized by mankind for over 9,000 years. Its leaves, flowers, roots, seeds and stem bark are been utilized in the form of herbal medicine to treat a number of ailments such as diabetes, ulcer, rheumatoid arthritis, cardiac disease, leucorrhoea, leprosy, fever etc.. The plant has also been reported to possess antimicrobial, antioxidant, hepatoprotective, hypoglycemic, anticancer, anti-inflammatory, antiparasitic, anti-dermatophytic and tuberculostatic properties due to the presence of bioactive compounds such as alkaloids, terpenoids, phenols, tannins, quinones, flavanoids, coumarins, carbohydrates, proteins and fatty acids etc.. The need for medicinal plants are now been rapidly increasing due to their low toxic nature and high pharmacological properties hence the present review is compiled to give a detailed insight in to the therapeutic potential of the important medicinal plant Lawsonia inermis L.

KEYWORDS: *Lawsonia inermis L., Medicinal plant, Phytochemistry, Herbal medicine, Bioactivity, Pharmacology.*

INTRODUCTION

Plants serve as a beneficial source to mankind in all aspects since its inception in the form of food, medicine and cosmetic. The modern drugs that are available now have their origin in traditional plant medicine which has been described by the practitioners for various diseases **[1].** Medicinal plants possess a wide range of secondary compounds such as alkaloids, phenols, flavanoids, glycosides, terpenoids, saponins… which play an essential role in drug formulation and therefore

been utilized in ancient traditional system of medication in many countries **[2]**. It has been estimated that about 80% people in developing countries rely on these traditional medicines for their primary health care and these are becoming popular due to their low toxic nature and ease of availability. This has led to a rapid increase in the number of herbal industries in the drug market. Many plant species have also been widely described in indigenous systems such as Siddha, Ayurveda, Unani and Allopathy for treating various disorders **[3]**. According to World Health Organization about 20,000 plant species are been utilized for their medicinal properties and approximately 3000 plant species are used as traditional medicines in India due to their pharmacological properties **[4]**.Plants with ethno-pharmacological importance are of great interest nowadays for the isolation of novel chemical compounds that could prove to be beneficial in all aspects of medication. Thus the present review is compiled to give a detailed insight into the various beneficial aspects of medicinal plant ***Lawsonia inermis*L.**

A. Medicinal plant -*Lawsonia inermis*L.

*Lawsonia inermis*L. is an evergreen medium sized shrub that belongs to the family Lythraceae. It is a monotypic genus commonly referred to as Henna/Mehndi. The genus *Lawsonia* bears only 1 species *L. inermis* having different synonyms such as "alba and spinosa". It is renowned as a medicinal and cosmetic agent in oriental parts of the world and widely cultivated as an ornamental and dye plant. It is a native of North Africa and South west Asia. It is widely distributedacross Sahel and Central Africa and also exists in Middle East. Plant is adapted to a wide range of environmental conditions and grows along waterways in semi-arid regions. It can also withstand low air humidity and drought conditions **[5], [6].**The taxonomical classification and Vernacular names of *Lawsonia inermis* L. are given in Table I& II.

Table I: Taxonomic Classification of *Lawsonia inermis* L.**[7], [8], [9].**

Kingdom	Plantae
Subkingdom	Tracheobionta
Superdivision	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Rosidae
Order	Myrtales
Family	Lythraceae
Genus	*Lawsonia*
Species	*inermis*
Botanical name	*Lawsonia inermis*L.

Table II: Vernacular names of *Lawsonia inermis* L.**[9], [10], [11],[12].**

Languages	***Lawsonia inermis*L.** (Vernacular names)
English	Henna, Cypress shrub, Camphire, Mignonette tree
Hindi	Mehndi
Tamil	Marudhani, aivanam, aivani
Malayalam	Mailanchi
Telugu	Goranta, kormmi
Kannada	Mayilanchi
Oriya	Benjati
Gujarati	Medi
Marathi	Mendhi, Mendi
Arabic	Yoranna, Hinna, Hena, Alhenna
Bengali	Mendi, Mehedi
Sanskrit	Timir, Mendika, Ragangi, Rakigarbha
Kashmiri	Mohuz
Amharic	Hina
Burmese	Dan
Chinese	Zhi jia hua
French	Henné,Jalousie,Fleurs,Reseda de France,Alcana d'orient
German	Hennastrauch
Indonesian	Inai,Pakar kuku
Javanese	Pacar kuku
Khmer	Krapeen
Laotian	Kaaw
Malay	Inai,Pacar kuku,Hinna
Portugese	Alfeneiro
Spanish	Alcana,Alhêna,Cinamomo,Reseda
Thai	Thian daeng,Thian khao,Thian king
Vietnamese	Nhuom mong tay,La mon
Greek	Kypros
Dominican republic	Resedon
Italian	Alcanna vera, arbusto della henna
Myanmar	Dan
Philippines	Cinamomo

B. Botanical description:

Lawsonia inermis L. is a branched glabrous shrub which measures about 2-6 m in height and is

spiny. It is cultivated as a hedge plant throughout India and also grown as a commercial crop in certain states of India for the production of dye that is mainly extracted from the leaves. Different parts of the plant are utilized for various medicinal properties among which bark, seeds and leaves are widely used medicinally.

Leaves are small, opposite in arrangement and appear greenish brown to dull green in colour. It measures about 1.5 to 5cm long and 0.5 to 2cm wide, sub-sessile, glabrous, entire margin is elliptic to broadly lanceolate, acute or obtuse apex with tapering base, Petioles very short, acuminate having depressed veins on dorsal surface. Flowers arenumerous, less than 1.3 cm, Fragrant, white or rose colored, in large terminal pyramidal panicled cymes. Pedicle is short less than 1.3 cm, numerous and slender in shape. Calyx is about 3-5mm long, broadly campanulate, lobes 2.5-3mm long, suborbicular/ subreniform, undulate. Flowers have petals that are obviate containingwhite / red stamens arranged in pairs on the rim of calyx tube.They contain 4 sepals and 2mm calyx tube.Ovary is 4 celled and 5mm long. Capsules are about 6mm in diameter, hlobose, slightly veined outside, supported by persistent calyx and tipped with style. Fruits are small, brownish round capsules which measures about 4-8mm in diameter, many seeded about 32-49 seeds per fruit, opening irregularly, splits into 4 sections with a persistent style. Seeds are brown pitted, 3mm across, angular, numerous, smooth, pyramidal in shape and possess a thick seed coat. Seed capsules are red, globose about the size of a pea with numerous tiny pyramidal brown pitted seeds. It requires high temperature for germination, growth and development. Young branches are green in color and quadrangular which turns red with age. Bark is greyish brown, unarmed when young but branches of old trees are spine tipped**(Figure 1) [4], [7], [10], [12].**

Figure 1:*Lawsonia inermis* L.**[3].**

C. Habitat and Distribution:

*Lawsonia inermis*L. is a popular medicinal plant in Jaffna peninsula, Sri Lanka and is geographically distributed in dry zones of Arabic countries, Persian countries, Egypt, India, Pakistan, USA (Florida), China and Sudan **[13], [14].** It is cultivated as an ornamental plant throughout India, Persia and along the African coast of the Mediterranean Sea and grows well in tropical savannah and arid zones in latitude between 15° and 25° N and S. The highest dye content is produced at a temperature of 35 to 45° C**[15].**The plants are mostly found in temporarily flooded river beds, in rock crevices and also on hill sides at elevations upto 1,350 metres **[16].**

D. Cultivation: Cultivation requires: **[16].**

- Mean annual temperature of 19 to 27° C but also tolerates 13 - 33° C
- Mean annual rainfall of 500- 1500 mm but tolerates 250 – 4200 mm
- Soil type: Mostly prefers fertile, well drained or dry soil and tolerant to poor, stony and sandy soils. It is well adapted to heavy, fertile, clay soil
- Optimum soil pH of 5 to 7 but tolerates pH range of 4.3 to 8 and
- Optimum temperature for germination is 25 to 30° C

REPORTED BIOACTIVE COMPOUNDS

A detailed overview on the bioactive components isolated from various parts of *Lawsonia inermis* L. as reported by different studies has been compiled **(Table III).**

Table III: Chemical constituents reported from different parts of *Lawsonia inermis* L.

S.No	Compound IUPAC name	Common Name	Compound class	Plant Part	Ref
1	5,7-dihydroxy-2-(4-hydroxyphenyl)chromen-4 -one	Apigenin	Flavanoid	Leaves& Aerial part	**[17], [19], [24], [45].**

2	5,7-dihydroxy-2-(4-hydroxy-3,5-dimethoxyphenyl)-6-methoxychromen-4-one	5,7,4'-trihydroxy-6,3',5'-trimethoxy flavone	Flavanoid	Leaves	**[17], [45].**
3	5,7-Dihydroxy-6-methoxy-2-(4-methoxyphenyl)chromen-4-one	Pectolinarigenin	Flavanoid	Leaves	**[17], [45].**
4	(5-hydroxy-2-(4-hydroxyphenyl)-7-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxychromen-4-one)	Apigenin-7-O-β-D-glucoside	Flavanoid	Leaves	**[17], [45].**
5	5-hydroxy-6-methoxy-2-(4-methoxyphenyl)-7-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-[[(2R,3R,4R,5R,6S)-3,4,5-trihydroxy-6-methyloxan-2-yl]oxymethyl]oxan-2-yl]oxychromen-4-one	Pectolinarin	Flavanoid	Leaves	**[17], [45].**
6	(3S,8S,9S,10R,13R,14S,17R)-17-[(2R,5R)-5-ethyl-6-methylheptan-2-yl]-10,13-dimethyl-2,3,6,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3-ol	Lawsaritol/ 24β-ethylcholest-4-en-3β-ol	Sterol	Root	**[18], [45].**
7	3,5,7-trihydroxy-2-(4-hydroxyphenyl)-6-methoxychromen-4-one	3,7,4',5'-Tetrahydroxy-6-methoxyflavone	Flavanoid	Root	**[18], [45].**
8	1-[2,4-dihydroxy-6-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxyphenyl]ethanone	2,4,6-trihydroxyacetophenone-2-O-β-D-glucopyranoside	Naphthoquinones	Leaves	**[19], [45].**
9	1-[3,4,6-trihydroxy-2-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxyphenyl]ethanone	Lalioside	Phenolic glycoside	Leaves	**[19], [45].**
10	5,7-dihydroxy-2-[3-hydroxy-4-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxyphenyl]chromen-4-one	Luteolin-4'-O-β-D-glucopyranoside	Flavanoid	Leaves	**[19], [45].**
11	5,7-dihydroxy-2-[4-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxyphenyl]chromen-4-one	Apigenin-4'-O-β-D-glucopyranoside	Flavanoid	Leaves	**[19], [45].**
12	2-(3,4-dihydroxyphenyl)-5,7-dihydroxychromen-4-one	Luteolin	Flavanoid	Leaves	**[19], [45].**
13	Tricetin 3',4',5' trimethyl ether 7-0-α-L rhamnopyranosyl (1→ 6) β-D glucopyranoside	---	Flavone glycoside	Whole plant	**[20].**
14	5,7-dihydroxy-2-(3,4,5-trimethoxyphenyl)chromen-4-one	5,7-dihydroxy-3',4',5'-trimethoxyflavone	Flavone glycoside	Whole plant	**[20], [45].**
15	3',4',5' trimethyl ether 7-0-β-D glucopyranoside	---	Flavone glycoside	Whole plant	**[20], [45].**
16	7-methoxy-1-methyl-9H-pyrido[3,4-b] indole	Harmine	Alkaloid	Seeds	**[21], [45].**
17	7-methoxy-1-methyl-4,9-dihydro-3H-pyrido[3,4-b]indole	Harmaline	Alkaloid	Seeds	**[21], [45].**
18	3H-pyran-2,6-dione	2H-Pyran-2,6 (3H)-dione	Carboxylic acid anhydride	Leaves	**[22], [45].**
19	3,5-dihydroxy-6-methyl-2,3-dihydropyran-4-one	4H-Pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl-	Volatile compound	Leaves	**[22], [45].**
20	Ethenoxybenzene	Benzene, (ethenyloxy)-	Epoxides	Leaves	**[22], [45].**
21	4-hydroxynaphthalene-1,2-dione	1,4-Naphthalenedione ,2-hydroxy-	Phenol	Leaves	**[22], [25].**
22	2-(hydroxymethyl)-6-methoxyoxane-3,4,5-triol	α-D-glucopyranoside, methyl	Monosaccharide	Leaves	**[22], [45].**

23	n-Hexadecanoic acid	Palmitic acid	Saturated fatty acid	Leaves	**[22], [45].**
24	4-Hydroxybenzoic acid	p- Hydroxy benzoic acid (PHBA)	Phenolic derivative of benzoic acid	Leaves	**[23], [45].**
25	(E)-3-(3,4-dihydroxyphenyl)prop-2-enoic acid	Caffeic acid	Polyphenol	Leaves	**[23], [45].**
26	[2,3-dihydroxy-5-[[(2R,3R,4S,5R,6S)-3,4,5,6-tetrakis[[3,4-dihydroxy-5-(3,4,5-trihydroxybenzoyl)oxybenzoyl]oxy]oxan-2-yl]methoxycarbonyl]phenyl]3,4,5-trihydroxybenzoate	Tannic acid	Polyphenol	Leaves	**[23], [45].**
27	(z) - 4,4'- (Prop-1-ene-1,3-diyl) diphenol	Phenol,4,4'-(1-methyl-1,2-ethenediyl)bis-	Diphenol	Aerial parts	**[24], [46].**
28	Methyl (1-oxo-1H-isochromen-3-yl)carbonate	Inermiscarbonate A	Isocoumarin carbonates	Aerial parts	**[24].**
29	Ethyl (1-oxo-1H-isochromen-3-yl)carbonate	Inermiscarbonate B	Isocoumarin carbonates	Aerial parts	**[24].**
30	2-(4-hydroxyphenyl)chromen-4-one	4'-hydroxyflavone	Flavanoid	Aerial parts	**[24], [45].**
31	3,5,7-trihydroxy-2-(4-hydroxyphenyl)chromen-4-one	Kaempferol	Flavanoid	Aerial parts	**[24], [45].**
32	2-(3,4-dihydroxyphenyl)-3,5,7-trihydroxychromen-4-one	Quercetin	Flavanoid	Aerial parts	**[24], [45].**
33	(2S,3R)-2-(3,4-dihydroxyphenyl)-3,4-dihydro-2H-chromene-3,5,7-triol	(-)-Catechin	Phenol	Aerial parts	**[24], [45].**
34	4-hydroxynaphthalene-1,2-dione	Lawsone	Naphthoquinone	Leaves	**[25], [45].**
35	(4aS,6aR,6aS,6bR,8aR,9S,10S,12aR,14bS)-10-hydroxy-9-[[(E)-3-(4-hydroxyphenyl)prop-2-enoyl]oxymethyl]-2,2,6a,6b,9,12a-hexamethyl-1,2,3,4,5,6,6a,7,8,8a,10,11,12,13,14b-tetradecahydropicene-4a-carboxylic acid	Lawsowaseem	Triterpenoid	Aerial part	**[45], [47], [48].**
36	1,7,7-trimethyltricyclo[2.2.1.0^{2,6}]heptane	Tricyclene	Bicyclic monoterpenoids	Leaves	**[26], [45].**
37	(1R)-1,3-dimethyl-8-propan-2yltricyclo[4.4.0.0 ^{2,7}] dec-3-ene	Alfa-copaene	Tricyclic sesquiterpenes	Leaves	**[26], [45].**
38	1-methyl-4-prop-1-en-2-ylcyclohexene	Cyclohexene,1-methyl-4-(1 methylethenyl)-,(r)	Cyclic monoterpene	Leaves	**[26], [45].**
39	(1R,4E,9S)-4,11,11-trimethyl-8-methylidenebicyclo[7.2.0]undec-4-ene	Caryophyllene	Bicyclic sesquiterpenes	Leaves	**[26], [45].**
40	(1Z,6Z)-cyclodeca-1,6-diene	1,6-Cyclodecadiene	Sesquiterpene	Leaves	**[26], [45].**
41	(1R,4R,6R,10S)-4,12,12-Trimethyl-9-methylen-5-oxatricyclo[8.2.0.0^{4,6}]dodecan	(-)-5-oxatricyclo[8.2.0.0(4,6)]dodecane	Bicyclic sesquiterpene	Leaves	**[26], [45], [49].**
42	1H-Cyclopropa[a]naphthalene	Methano naphthalene	Sesquiterpene	Leaves	**[26], [45].**
43	Dotriacontane	n-Dotriacontane	Alkane	Leaves	**[26], [45].**
44	Tetradecanoic acid	Myristic acid	Saturated fatty acid	Leaves	**[26], [45]**
45	7,11,15-trimethyl-3-methylidenehexadec-1-ene	Neophytadiene	Diterpene	Leaves	**[26], [45].**
46	Pentadecanoic acid	Pentadecyclic acid	Saturated fatty acid	Leaves	**[26], [45].**
47	(E)-3,7,11,15-tetramethylhexadec-2-en-1-ol	3,7,11,15-tetramethyl-2-hexadecen-1-ol	Acyclic diterpene alcohol	Leaves	**[26], [45].**
48	(Z)-octadec-9-enoic acid	Oleic acid / Cis-9-octadecanoic acid	Fatty acid	Leaves	**[26], [45].**

49	dibutyl nonanedioate	Nonanedioic acid,dibutyl ester	Saturated dicarboxylic acid	Leaves	**[26], [45].**
50	[(2S)-2-[(2R)-4-hexadecanoyloxy-3-hydroxy-5-oxo-2H-furan-2-yl]-2-hydroxyethyl] hexadecanoate	L-(+)-Ascorbic acid 2,6 dihexadecanoate	Fatty acid ester	Leaves	**[26], [45].**
51	Heptadecanoic acid	Margaric acid	Saturated fatty acid	Leaves	**[26], [45].**
52	docosan-1-ol	Behenic alcohol	Saturated fatty alcohol	Leaves	**[26], [45].**
53	(4aS,6aR,6aS,6bR,8aR,10R,11R,12aR,14bS)-11-acetyloxy-10-hydroxy-2,2,6a,6b,9,9,12a-heptamethyl-1,3,4,5,6,6a,7,8,8a,10,11,12,13,14b-tetradecahydropicene-4a-carboxylic acid	Lawsoshamim	Triterpenoid	Aerial part	**[26], [45], [47], [50].**
54	Methyl octadecanoate	Methyl stearate	Ester	Leaves	**[26], [45].**
55	Octadecanoic acid	Stearic acid	Saturated fatty acid	Leaves& Seeds	**[26], [28], [45].**
56	methyl icosa-11,14-dienoate	Cis-11,14-Eicosadienoic acid,methyl ester	Ester	Leaves	**[26], [45].**
57	Nonadecanoic acid	Nonadecyclic acid	Saturated fatty acid	Leaves	**[26], [45].**
58	(3-hexadecanoyloxy-2-hydroxypropyl) hexadecanoate	Hexadecanoic acid,2 hydroxy-1,3-propanediyl ester	Diglyceride	Leaves	**[26], [45].**
59	Octadec-9-enoic acid	9- octadecenoic acid	Fatty acid	Leaves	**[26], [45].**
60	Icosanoic acid	Arachidic acid	Saturated fatty acid	Leaves&Seeds	**[26], [28], [45].**
61	[2-hydroxy-3-[(E)-octadec-9-enoyl]oxypropyl] (E)-octadec-9-enoate	Glycerol-1,3-dielaidate	Glycerol with two monounsaturated fatty acid chains	Leaves	**[26], [45].**
62	(6E,10E,14E,18E) -2,6,10,15,19,23-hexamethyltetracosa-2,6,10,14,18,22-hexaene	Squalene	Triterpene	Leaves	**[26], [45].**
63	Oxiran-2-ylmethyl octadecanoate	Glycidol stearate	Fatty acid derivative	Leaves	**[26], [45].**
64	naphthalene-1,4-dione	Naphthoquinone	Organic compound	Bark	**[10], [45], [51].**
65	8-hydroxy-2-methylnaphthalene-1,4-dione	Isoplumbagin	Naphthoquinones	Bark	**[10], [45].**
66	(1R,3aR,5aR,5bR,7aR,9S,11aR,11bR,13aR,13bS)-1-(3-hydroxyprop-1-en-2-yl)-3a,5a,5b,8,8,11a-hexamethyl-1,2,3,4,5,6,7,7a,9,10,11,11b,12,13,13a,13b-hexadecahydrocyclopenta[a]chrysen-9-ol	Hennadiol	Triterpenoids	Bark	**[10], [45].**
67	3-methylnonacosan-1-ol	1-Nonacosanol, 3-methyl-	Aliphatics	Bark& Aerial part	**[10], [43], [45].**
68	(E)-4-(2,6,6-trimethylcyclohex-2-en-1-yl)but-3-en-2-one	α-ionone	Terpenoids	Flowers	**[27], [45].**
69	(E)-4-(2,6,6-trimethylcyclohexen-1-yl)but-3-en-2-one	β-ionone	Terpenoids	Flowers	**[27], [45].**
70	Docosanoic acid	Behenic acid	Fatty acids	Seeds	**[28], [45].**

71	(9Z,12Z)-octadeca-9,12-dienoic acid	Linoleic acid	Fatty acids	Seeds	**[28], [45].**
72	Hexadecanoic acid	Palmitic acid	Saturated Fatty acid	Seeds	**[28], [45].**
73	1,2,4-trihydroxynaphthalene-1-0-β-D-glucopyranoside	--	Phenolic glycoside	Leaves	**[29], [45].**
74	(2R,3S,4S,5R,6S)-2-(hydroxymethyl)-6-[3-hydroxy-4-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxynaphthalen-1-yl]oxyoxane-3,4,5-triol	Lawsoniaside	Phenolic glycoside	Leaves	**[29], [45].**
75	2-(3,4-dihydroxyphenyl)-5-hydroxy-7-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxychromen-4-one	Luteoloside	Flavanoid	Leaves	**[29], [45].**
76	1, 3-dihydroxy-6, 7-dimethoxyxanthone	Laxanthone I	Xanthone	Whole plant	**[10], [52].**
77	1-hydroxy-3, 6-diacetoxy-7-methoxyxanthone	Laxanthone II	Xanthone	Whole plant	**[10], [52].**
78	1-hydroxy-6-acetoxy xanthone	Laxanthone III	Xanthone	Whole plant	**[3], [10].**
79	Triacontan-1-ol	n-Triacontanol	Fatty alcohol	Whole plant	**[10], [45].**
80	6,7-dihydroxychromen-2-one	Esculetin	Coumarin	Leaves	**[30], [45].**
81	7,8-dihydroxy-6-methoxychromen-2-one	Fraxetin	Coumarin	Leaves	**[30], [45].**
82	7-hydroxy-6-methoxychromen-2-one	Scopoletin	Coumarin	Leaves	**[30], [45].**
83	7-hydroxy-5-methylchromen-2-one	7-Hydroxy-methyl coumarin	Coumarin	Stem	**[31], [45].**
84	4-hydroxychromen-2-one	4-Hydroxy coumarin	Coumarin	Stem	**[31], [45].**
85	5-allyoxy-7-hydroxycoumarin	Lacoumarin	Coumarin	Whole plant	**[32], [45].**
86	----	Lawsochrysin	Flavanoids	Leaves	**[33].**
87	----	Lawsonaringenin	Flavanoid	Leaves	**[33].**
88	7-hydroxy-2-phenylchromen-4-one	7-Hydroxyflavone	Flavanoid	Leaves	**[33], [45].**
89	7-[(2S,3R,4S,5S,6R)-4,5-dihydroxy-6-(hydroxymethyl)-3-[(2S,3R,4R,5R,6S)-3,4,5-trihydroxy-6-methyloxan-2-yl]oxyoxan-2-yl]oxy-5-hydroxy-2-(4-hydroxyphenyl)chromen-4-one	Rhoifolin	Flavone glycoside	Leaves	**[33], [45].**
90	2-phenylethanol	2-Phenylethyl alcohol	Naphthoquinones	Flowers	**[34], [45].**
91	(4S)-4-hydroxy-4-[(E,3R)-3-hydroxybut-1-enyl]-3,5,5-trimethylcyclohex-2-en-1-one	Vomifoliol	Terpenoid	Aerial part	**[35], [45].**
92	(1R,3aR,5aR,5bR,7aR,9S,11aR,11bR,13aR,13bR)-3a,5a,5b,8,8,11a-hexamethyl-1-prop-1-en-2-yl-1,2,3,4,5,6,7,7a,9,10,11,11b,12,13,13a,13b-hexadecahydrocyclopenta[a]chrysen-9-ol	Lupeol	Triterpenoid	Bark	**[36], [45].**

93	(1R,3aS,5aR,5bR,7aR,9S,11aR,11bR,13aR,13bR)-3a-(hydroxymethyl)-5a,5b,8,8,11a-pentamethyl-1-prop-1-en-2-yl-1,2,3,4,5,6,7,7a,9,10,11,11b,12,13,13a,13b-hexadecahydrocyclopenta[a]chrysen-9-ol	Betulin	Triterpenoid	Bark	**[36], [45].**
94	(1R,3aS,5aR,5bR,7aR,9S,11aR,11bR,13aR,13bR)-9-hydroxy-5a,5b,8,8,11a-pentamethyl-1-prop-1-en-2-yl-1,2,3,4,5,6,7,7a,9,10,11,11b,12,13,13a,13b-hexadecahydrocyclopenta[a]chrysene-3a-carboxylic acid	Betulinic acid	Triterpenoid	Bark	**[36], [45].**
95	(20S)-3β,30-Dihydroxylupane	--	Terpenoids	Bark	**[37].**
96	(3R,4S,5S,6R)-2-(3,4-dihydroxynaphthalen-1-yl)oxy-6-(hydroxymethyl)oxane-3,4,5-triol	1, 2-dihydroxy-4-glucosyloxy naphthalene	Hydrocarbon	Leaves	**[38], [45].**
97	(2R,3R,4S,5S,6R)-2-[[(3S,8S,9S,10R,13R,14S,17R)-17-[(2R,5R)-5-ethyl-6-methylheptan-2-yl]-10,13-dimethyl-2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3-yl]oxy]-6-(hydroxymethyl)oxane-3,4,5-triol	β-sitosterol-3-O-β-D-Glucoside	Steroids	Leaves	**[39], [45].**
98	(3S,8S,9S,10R,13R,14S,17R)-17-[(2R,5R)-5-ethyl-6-methylheptan-2-yl]-10,13-dimethyl-2,3,6,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3-ol	Lawsaritol	Steroids	Roots	**[40], [45].**
99	Balanitisin A	--	Steroidal saponin	Fruits	**[41].**
100	D-Glucose	Glucose	Sugar	Whole plant	**[31], [45].**
101	(2R,3R,4S,5S,6R)-2-ethoxy-6-(hydroxymethyl) oxane-3,4,5-triol	2-0-Ethyl-β-D-glucopyranoside	Sugar	Stem	**[31], [45].**
102	12-[2'-(1',4'-Dioxin-5',6-dione)-8" E-undecenyl-dodecanoate	--	Dioxin derivative	Stem	**[42].**
103	5-[1'(Docosa-2'E,5'E-dienyl)]-1,4-dioxin-2,3-dione	--	Dioxin derivative	Stem	**[42].**

A. Structures of bioactive compounds isolated from *Lawsonia inermis*L.

The structures of some important bioactive compounds isolated from various parts of *Lawsonia inermis* L. as reported by different studies has been collected and compiled in this review.

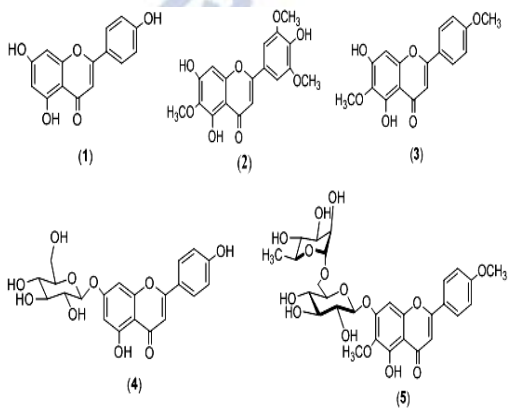

Figure 2: Structure of isolated **Compound 1:** Apigenin, **Compound 2:** 5,7,4'-trihydroxy-6,3',5'-trimethoxyflavone, **Compound 3:** Pectolinarigenin, **Compound 4:** Apigenin-7-0-β-D-glucoside, **Compound 5:** Pectolinarin**[17].**

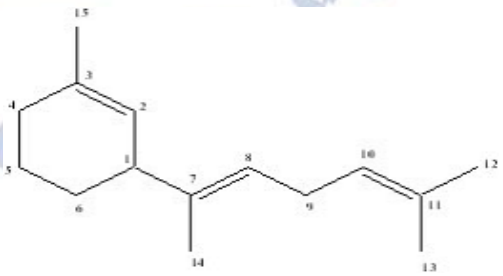

Figure 3: Chemical structure of compound Bisabolene **[44].**

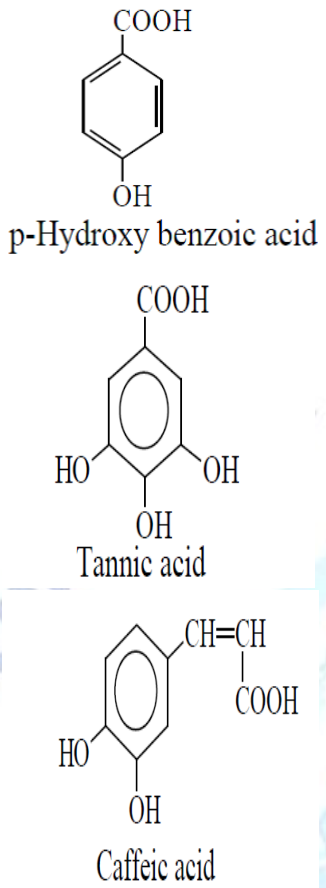

Figure 4: Bioactive compounds isolated from the leaves of *Lawsonia inermis*L.**[53].**

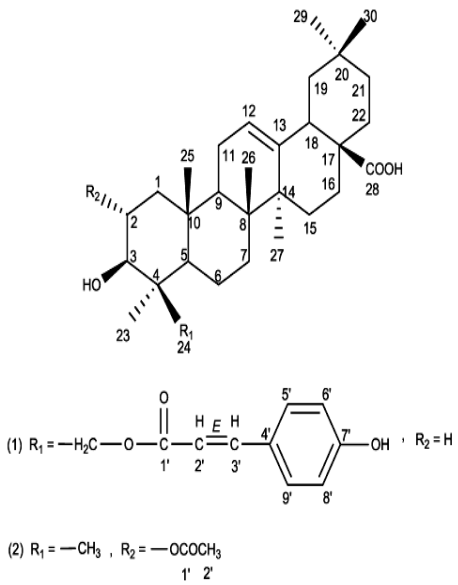

Figure 5: Structure of triterpenoids isolated from the aerial parts of *Lawsonia inermis*L. **Compound 1:** Lawsowaseem and **Compound 2:** Lawsoshamim **[47].**

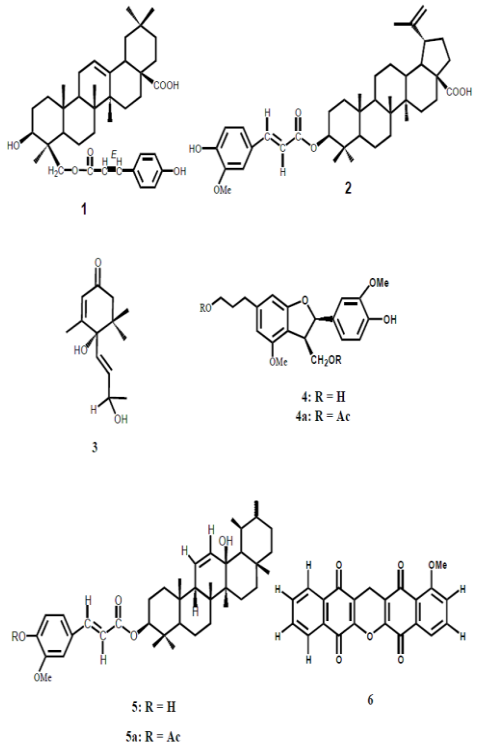

Figure 6: Structures of isolated compounds from *Lawsonia inermis* L. **Compound 1:** Lawsowaseem, **Compound 2:** Lawsonic acid, **Compound 3:** Vomifoliol, **Compound 4:** Lawsonicin, **Compound 5:** Lawsonin, **Compound 6:** Lawsonadeem, **Compound 4a,5a:** Acetyl derivatives of Lawsonicin and Lawsonin**[48].**

ETHNOMEDICINAL APPLICATIONS

Different parts of *Lawsonia inermis*L. were reported to possess various ethnomedicinal applications and some are listed below: **[54], [55].**

- **Leaves:**Paste of *Lawsonia inermis*L. leaves are been used in treating various skin related disorders such as alopecia, scabies, Athlete's foot, dandruff, cracked heels, prickly heat, ringworm infection, hair fall, leprosy, eczema etc. Leaves are diuretic, expectorant, emetic and vulnerary. The leaf paste is also been used traditionally for coloring hair as well as in the treatment of jaundice, hepatitis, skin and venereal diseases, small pox and spermatorrhoea. Leaf infusions arealso used as topical applications in bruises and sprains. Decoction is used as an astringent gargle in sore throat.
- **Flowers:** Flowers arewidely used in perfumery and are considered refrigerant and vulnerary. Flower infusions are applied topically to treat bruises and also cures headache. Decoction of flower is used as an emmenagogue.

- **Seed:** Seed is powdered, mixed with butter and used as remedy against liver disorders. It is considered to be a brain tonic and its oil possess both antibacterial and antifungal activity and also found to be effective against dysentery.
- **Bark:** The bark is considered emmenagogue.Decoction is applied on burnt area and scalds. It is used in the treatment of hepatitis, spleen enlargement, skin infections, Jaundice and as an alternative in leprosy.
- **Root:** Used in treating sore eyes, hysteria, gonorrhoea, herpes infection and nervous disorders. Pulped root is also used in treating boils.

PHARMACOLOGICAL APPLICATIONS

Pharmacological activities of *Lawsonia inermis*L. as reported by various studies are compiled in this review.

Antidiabetic activity: 70% ethanolic extract of *Lawsonia inermis*L. have been reported to have shown hypoglycemic and hypolipidaemic activities after oral administration in alloxan induced diabetic rats at a time span of 0,3,7 and 14th day wherein the concentration of glucose reduced from 194 mg dL $^{-1}$ to normal, cholesterol concentration decreased from 148.9 to 55.3 mg dL $^{-1}$ while triglyceride concentration decreased from 225.7 to 76.9 mg dL $^{-1}$ after 14th day. Also it has been reported that 95% methanol extract of *Lawsonia inermis*L. leaves do possess some significant antihyperglycemic activity when tested *In vitro* **[56],[57].**

Antibacterial and Antifungal activity: Ethanolic extracts of *Lawsonia inermis* L. were tested in a study for its efficacy against both Gram positive and Gram negative bacteria wherein the active ethanolic extract was partitioned between ethyl acetate and water. The ethyl acetate extract was found to have shown good inhibition zone and was reported to be the most active fraction against all tested pathogens **[58]**.Extracts from the bark of *Lawsonia inermis*L. was also found to exhibit significant fungitoxicity against *Microsporum gypseum* and *Trochophyton mentgrophytes*.Ethanol,methanol and aqueous extracts of *Lawsonia inermis*L. leaves were also found to have displayed high antifungalactivity against all fungal pathogens.Certain solvent extracts such as petroleum ether,benzene,chloroform,methanol and ethanol extracts also showed significant antifungal activity**[59],[60].**

Antioxidant activity: 80% ethanolic extract of *Lawsonia inermis*L. leaves were investigated on drug metabolizing Phase I and Phase II enzymes, antioxidant enzymes, glutathione content, lactate dehydrogenase and lipid peroxidation through an *In vivo* study in the liver of swiss albino mice wherein the activity of the antioxidant enzymes such as hepatic glutathione reductase, superoxide dismutase and catalase were found to have shown an increase with increasing dose level .The total phenolic content in the methanol and aqueous extracts were reported to be of about 2.56 and 1.45 mg tannic per mg of henna dry matter. Chloroform extract of *Lawsonia inermis* L. leaveswere reported to have shown 87.6% activity than alpha-tocopherol with 62.5% activity by FTC method while the extract showed 55.7 % activity followed by alpha tocopherol with 44.4% by TBA method **[61], [62].**

Trypsin inhibitory activity: The ethanolic extract of *Lawsonia inermis*L. and its active component lawsone has also been reported to have shown Trypsin inhibitory activity with an IC50 value of about 64.87 and 48.6µg/ml**[63].**

Cytotoxic activity: Chloroform extract of *Lawsonia inermis*L. leaves were reported to have displayed cytotoxic effect against liver (HepG2) and human breast cancer cell line (MCF-7) with an IC50 value of 0.3 and 24.85 µg/ml by MTT (Microculture tetrazolium salt assay) **[64].**

Hepatoprotective activity: Alcoholic extract of *Lawsonia inermis* L. bark was reported to exhibit hepatoprotective effect against carbon tetrachloride induced elevation in serum marker enzymes, serum bilirubin, liver lipid peroxidation, liver glutathione, glutathione-s-transferase, superoxide dismutase and catalase activity. The extract was also found to inhibit the peroxidation of microsomal lipids in dose dependent manner **[65]**. The ethanolic extract of *Lawsonia inermis*L. leaves and its crude fractions (petroleum ether, ethyl acetate, butanol and butanone fractions) were also reported to have shown a decrease in total bilirubin content and SGOT, SGPT and SAL activities through an *In vivo* study **[66], [67].**

Immunomodulatory activity: Methanolic extract of *Lawsonia inermis*L. leaves were found to have shown immunostimulant activity by promotion of T-lymphocyte proliferative response and also 7 different compounds were reported to have been isolated from the methanolic extract through lymphocyte transformation assay guided

fractionation wherein naphthoquinone fraction displayed significant immunomodulatory activity **[68].**

Antiviraland tuberculostatic activity: The ethanol fraction of *Lawsonia inermis*L. fruits displayed high antiviral activity against Sembiki forest virus (SFV) in swiss mice and chick embryo models showing 100 to 65% activity**[69].**Tuberculostatic activity of *Lawsonia inermis*L. was determined through *In vitro* and *In vivo* studies wherein *In vitro* study using *Mycobacterium tuberculosis* and *In vivo* study using guinea pigs and mice were found to have displayed potential activity of the extract **[70].**

Anti-inflammatory activity: Certain compounds isolated from the stem bark and root of *Lawsonia inermis*L. such as Isoplumbagin and lawsaritol were reported to have shown potential anti-inflammatory activity in Carrageenan induced paw oedema in rats. The active principles from the leaves of *Lawsonia inermis*L. along with butanol and chloroform fractions were also found to have shown significant anti-inflammatory activity **[71], [72].**

Antidermatophytic activity: Ethanol, ethyl acetate and hexane extracts of *Lawsonia inermis*L. were tested against *Tinea rubrum* and *Tinea mentagrophytes* and were found to have exhibited potential anti-dermatophytic activity through an *In vitro* study **[73].**

Analgesic and Antipyretic activity: The leaf extracts of *Lawsonia inermis*L. was reported to have displayed significant analgesic and antipyretic activities however the fixed oil derived from seeds were found to be devoid of behavioral and CNS effects and failed to produce any effect on the isolated tissue **[74].**

Anticoagulant and Antisickling activity: Lawsone and its oxazine derivatives isolated from the leaves of *Lawsonia inermis*L. have proved to be an effective anticoagulant agent **[75].** Aqueous extract of *Lawsonia inermis*L. leaves were found to inhibit sickling thereby increasing oxygen affinity of HbSS blood **[76].**

Wound healing activity: Aqueous and chloroform extracts of *Lawsonia inermis*L. leaves were found to be capable of inhibiting the growth of microbes that are responsible of causing burn wound infections. The *In vivo* wound healing activity of ethanolic extract were evaluated on rats using excision,incision and dead space wound models wherein the extract exhibited high rate of wound contraction compared to that of control and reference standard **[77],[78].**

Protein glycation inhibitory activity: The *In vitro* protein glycation inhibitory activity of ethanol extract and the compounds lawsone and gallic acid isolated from *Lawsonia inermis*L. plant tissues were evaluated in a study using bovine serum albumin and glucose as model systems wherein both extract and its components showed significant inhibition of advanced glycated end products formation and exhibited 77.95%, 79.10% and 66.98% inhibition **[79]**.

Nematicidal and Molluscicidalactivity: *Lawsonia inermis*L. was found to have shown suppressive effect against *Meloidogyne incognita* development. The study reported that henna showed reduced tomato root gall numbers, number of egg laying females and rate of nematode production when grown along with tomato while when grown alone the rate of nematode production reduced nearly to 75% and 99% **[80].***Lawsonia inermis*L. leaf, bark and seed were also reported to have shown potential molluscicidal activity against *Lymnaea acuminata* and *Indoplanorbis exustus***[81].**

Anti-helmintic activity: Chloroform, ethanol and aqueous extracts of *Lawsonia inermis*L. were tested for their anti-helmintic activity using adult earthworm *Eisenia foetida*at different concentrations such as 10, 20, 50 and 100mg/ml wherein all the extracts showed potential activity and among the extracts aqueous extract was reported to have shown better activity**[82].**

Nootropic activity: The acetone fraction of petroleum ether extract of *Lawsonia inermis*L. exhibited prominent Nootropic activity and its effect on memory was assessed using elevated plus maze and passive shock avoidance paradigms. Thereby *Lawsonia inermis*L. possessed a potential for exploring a Nootropic principle **[83].**

CONCLUSION

Lawsonia inermis L. is a plant with multifunctional aspects and has a wide role in pharmaceutical, industrial and environmental applications. They are found to possess innumerable secondary compounds such as alkaloids, phenols, tannins, glycosides, saponins etc. that are reported to show various pharmacological importance as mentioned in this review. Different parts of the plant such as leaves, flowers, fruits, seed, bark, root serves different functions but are not much completely

explored. Many more studies should be carried out in order to understand their diversified properties and their pharmaceutical potential.So this review has been compiled to give a brief idea about the extensive distribution of secondary compounds, their roles, ethnomedicinal properties and various beneficial as well as pharmacological aspects of a widely known medicinal plant *Lawsonia inermis* L.

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