A review on anthraquinones isolated from Cassia species and their applications

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Cassia Linn. (Family — Caesalpiniaceae) is a large tropical genus with about 600 species of herbs, shrubs and trees. Most of the plants of the genus are wellknown in Indian system of medicine for their cathartic, purgative and antibiotic properties. Many compounds of structural significance and medicinal importance have been reported from different species of this genus. Species of Cassia are rich source of anthraquinones which are wellknown as natural dyes, and are gaining importance in recent years due to environmental pollution caused by synthetic dyes. This paper attempts to give an overview of literature on the isolated and characterized anthraquinones from various Cassia species and their reported applications. Besides dye yielding properties they are used in cosmetics and pharmaceuticals. Thus plants of Cassia species can serve as commercial source of naturally occurring anthraquinones.

Keywords: Anthraquinones, Biologically active metabolites, Cassia, Caesalpiniaceae, Pharmacological applications.

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Introduction

Various natural products have been isolated from number of plant species. These isolated natural products have remarkable variety of compounds having unusual structures, many of which have found uses in the cosmetic dye and pharmaceutical industries. In addition these compounds are plant growth regulators, fungicides, insecticides, pest control agents and repellents of herbivores. With increase in awareness about environment and sustainable development natural products found to be new area of research due to its biodegradable nature and production from renewable resources. Review of compounds isolated from plant is important as these compounds have served as lead compounds for additional research, or that continue to be of interest to researchers in multiple areas¹. Anthraquinones are one of such compounds which occur naturally in some plants, fungi, lichens, and insects, where they serve as a basic skeleton for their pigments. Natural anthraquinones are study of interest due to its wide range of applications.

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Anthraquinones are group of functionally diverse aromatic chemicals, structurally related to anthracene, with parent structure 9,10-dioxoanthracene. It has the appearance of yellow or light gray to gray-green solid crystalline powder. Its other names are 9,10-anthracenedione, anthradione, 9,10-anthrachinon, anthrace-9,10-quinone and 9,10-dihydro-9,10-dioxoanthracene. The vegetables used in human diet showed a large batch-to-batch variability, from 0.04 to 3.6, 5.9 and 36 mg total anthraquinone per kg fresh weight in peas, cabbage, lettuce and beans, respectively with physcion predominated in all vegetables². Anthraquinone compounds are used as laxatives mainly from their glycosidic derivatives and also used in the treatment of fungal skin diseases³. Anthraquinones and its derivatives are frequently found in slimming agents and have been valued for their cathartic and presumed detoxifying action however, may cause nausea, vomiting, abdominal cramps and diarrhoea with both therapeutic dose and over dose³. Anthraquinone derivatives show antioxidant property in following order: BHA (96%), anthrone (95%), alizarin (93%), aloe-emodin (78%), rhein (71%), emodin (36%) and anthraquinone (8%)⁴.
Both natural and synthetic anthraquinones have wide-spread applications throughout industry and medicine, thereby indirectly and directly exposing the human population\(^1\). Plant extracts containing anthraquinones are being increasingly used for cosmetics, food, dye and pharmaceuticals due to their wide therapeutic and pharmacological properties\(^6\). Some of the reported applications of anthraquinones and their chemical structures are summarized in Table 1(Refs 6-28) and Figs 1-37.

**Anthraquinone from various *Cassia* species**

*Cassia* Linn. a major genus of Caesalpiniae family, contains four sections comprising about 600 species; some of which widely distributed throughout the world especially in tropical countries and is abundantly available in India. The genus *Cassia* is widely distributed in tropical and subtropical regions and is used in traditional folk medicine, particularly for the treatment of periodic fever and malaria. The species are good source of mucilage, flavonoids, anthraquinones and polysaccharides\(^29\). Several of them yield timber, tannins and dyes, fodder, vegetables, edible fruits and seeds used as substitute for coffee. About 45 species are found in India of which few have been introduced for ornament\(^30\). There are 28 tropical species in *Cassia* Linn. sect. Fistula and six of these, viz. *C. grandis* Linn., *C. fistula* Linn., *C. nodosa* Hamilt, *C. renigera* Wall., *C. javanica* Linn. and *C. marginata* Roxb. are found in Indian flora. Phytochemical investigation reveals that all six species contain kaempherol and a mixture of anthraquinones which include chrysophanol (Fig. 1), rhein (Fig. 2) and physcion (Fig. 3)\(^7\). Formation of hydroxyanthraquinone has been demonstrated in cell cultures of *C. angustifolia* Vahl, *C. senna* Linn. and *C. tora* and they are important source of anthraquinone laxtatives. The hydroxyl anthraquinones are synthesized in these plants via the acetate malonate pathway\(^32\). A large number of anthraquinones are identified from various parts of cassia species are reported and described\(^30\). In the following text, anthraquinones from different cassia species are reviewed along with pharmacological properties of cassia species due to presence of anthraquinones.

**Cassia absus** Linn.

It is an erect, annual plant 30-60 cm high, distributed throughout India. All plant parts of the species are used in folk medicine. The leaves are bitter, acrid and astringent. The seeds are used in the treatment of ophthalmia and skin infections and as cathartic. The seeds are also used in syphilitic ulcers and leucoderma\(^33\). The leaves are used in treatment of tumors and asthma, while roots are used for treatment of constipation. The reported medicinal uses of roots are consistent with the presence of chrysophanol (Fig. 1) and aloe-emodin (Fig. 4) (Table 2)\(^34\).

**Cassia acutifolia** Delile

It is native to India and cultivated mainly in South India and Pakistan. The parts of this plant used medicinally are the leaves and pods. The leaves have purging quality, but afterwards have binding effect. Both the leaves and pods are used in many over-the-counter pharmaceutical preparations. It is a purgative having active ingredients anthraquinone derivatives and their glucosides, acting on the lower bowel, and is especially useful in alleviating constipation. Various anthraquinones reported from different plant parts (Table 2) supports its medicinal properties\(^35,36\).

Nazif *et al* (2000) had studied the effect of salt stress on suspension cultures of *C. acutifolia* established by transferring callus tissues derived from root, hypocotyl and cotyledon explants onto liquid MS-medium supplemented with 1.0 mg/l 2,4-D and 0.1 mg/l kinetin and containing increasing levels of NaCl and reported that stress induced by NaCl raised anthraquinone content and reduced growth of cultures. The levels of anthraquinones and their glucosides as sennosides showed distinct changes in cells and media as well as in the different cultures initiated from various explants. Furthermore, the salt stress tended to affect more drastically the productivity of anthraquinones in hypocotyl and cotyledon cell cultures than in root cultures\(^35\).

**Cassia alata** Linn.

It is a native of tropical America but now widely distributed in tropics mainly in western and eastern Africa and India. Its seeds are reported to be alternative of legumes due to high protein and carbohydrates\(^37\). It is a pantropical, ornamental shrub, which commonly known as Ringworm Senna as the leaf extract of the plant have been reported to possess medicinal properties against ringworm, scabies, ulcers and other skin diseases such as pruritis, eczema and itching\(^38\). Aqueous extract of the plant could be used effectively as antidermatophytic agents as it inhibits the ringworm infection. The leaves in the form of
<table>
<thead>
<tr>
<th>Anthraquinone R eported Uses</th>
<th>Ref. No.</th>
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<tr>
<td>Antiviral activity, anthraquinone-loaded liposomes may suppose an alternative for antimicrobial, pharmaceutical or cosmetic applications</td>
<td>6</td>
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<tr>
<td>Inhibit respiratory sulfate reduction by pure cultures of sulfate-reducing bacteria, as well as by crude enrichment cultures</td>
<td>7</td>
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<tr>
<td>Innovative and safe chemotherapeutic strategy can be developed that uses natural anthraquinone derivatives as reactive oxygen species generators to increase the susceptibility of tumour cells to cytotoxic therapeutic agents</td>
<td>8</td>
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<tr>
<td>Long-term ingestion of certain anthraquinones, may affect the toxicity of other components present in the diet through the hepatic induction or inhibition of P450 1A2</td>
<td>9</td>
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<td>Inhibitory activities on photosystem II electron transport</td>
<td>10</td>
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<tr>
<td>Enhancements to enzymatic cutting of DNA were observed cluster around AT-rich regions.</td>
<td>11</td>
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<tr>
<td>Significant antigenotoxic activities against the eight carcinogens</td>
<td>12</td>
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<tr>
<td>MAC 16 may provide a lead for the development of novel generations of anthraquinone-type antitumor agents</td>
<td>13</td>
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<tr>
<td>Pt-1C3 complex may represent an effective system for the delivery of the platinum moiety to nuclear DNA</td>
<td>14</td>
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<tr>
<td>Strongly suppressed DNA-binding activity of the aryl hydrocarbon receptor (AhR) induced by 0.1 M 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), with their IC50 values around 1 µM. The findings of this study may be useful for the design of the novel antagonists of the aryl hydrocarbon receptor (AhR)</td>
<td>15</td>
</tr>
<tr>
<td>Moderate yields (35-45%) of 3-alkynals by photolysis which has potential to play an important role in synthesis by selective reaction of their isolated functional groups</td>
<td>16</td>
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<tr>
<td>Inactivate enveloped viruses</td>
<td>17</td>
</tr>
<tr>
<td>Antiviral and virucidal activities against viruses representing several taxonomic groups</td>
<td>18</td>
</tr>
<tr>
<td>Anti-HIV-1 activity</td>
<td>19</td>
</tr>
<tr>
<td>Antiviral activity against vesicular stomatitis virus, herpes simplex virus types 1 and 2, parainfluenza virus, and vaccinia virus, HIV-1, retroviruses at conc. of less than 1 µg/ml</td>
<td>18,19</td>
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<tr>
<td>Antiviral activity against human cytomegalovirus (HCMV)</td>
<td>20</td>
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<tr>
<td>These compounds could be a prototype for synthesizing even more effective HCMV-inhibitory anthraquinone derivatives</td>
<td>21</td>
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<tr>
<td>Inhibit the replication of poliovirus types 2 and 3</td>
<td>22</td>
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<td>1-hydroxyl and 4-hydroxyl groups in the anthraquinone structure are key factors in hypersensitivity induction by anthraquinone-related compounds</td>
<td>23</td>
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<td>Accelerating effect of anthraquinone as a redox mediator in the biodecolorization of dispersed organic dyestuffs</td>
<td>24</td>
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<td>Decolorization of azo dyes using the salt-tolerant bacteria</td>
<td>25</td>
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<td>Broad and intense absorption spectra in the visible region (up to 800 nm)</td>
<td>26</td>
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<tr>
<td>Quench bacteriorhodopsin tryptophan fluorescence</td>
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<tr>
<td>Anthraquinone anions that are responsible for the O2− generation in polar solvent</td>
<td>28</td>
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</tbody>
</table>
Figs 1-15 — Chemical structures of some anthraquinines present in *Cassia* species

1. Chrysophanol
2. Rhein
3. Physcion
4. Aloe-edomin
5. Emodin
6. Rhein-8-monoglucoside
7. Sennidin
8. 1,5,7-trihydroxy-3-methylantraquinone (alatine)
9. 2-formyl-1,3,8-trihydroxy-anthraquinone
10. diacerein (1,8-diacyl derivative of rhein)
11. sennoside A
12. sennoside B
13. sennoside C
14. sennoside D
15. two isomeric aloe-edomin dianthrone diglucosides
Figs 16-27 — Chemical structures of some anthraquinones present in Cassia species
paste with or without lime juice are regarded as an excellent topical remedy for ringworm in Indian native medicinal. Decoction of wood is useful in cases of constipation. Crude ethanol and water extract of barks shown in vitro antimicrobial activity against fungi, yeast, and bacteria, while water extract exhibited higher antibacterial activity than the ethanol extract from leaves. The methanol extracts of leaves, flowers, stem and root barks of showed a broad spectrum of antibacterial activity while the dichloromethane fraction of the flower extract being the most effective. Various authors have reported...
antifungal properties of extracts of its leaves and isolated anthraquinones (Table 2) as main constituents for antifungal effect\textsuperscript{30,43-46}. Damodaran and Venkataraman (1994) reported the therapeutic efficacy of \textit{C. alata} leaf extract against \textit{Pityriasis versicolor} for the first time involving humans. The study indicated that the leaf extract can be reliably used as an herbal medicine to treat \textit{P. versicolor} without any side-effects on humans\textsuperscript{37}.

Leaf extract of \textit{C. alata} has been shown to reduce the blood sugar value in streptozotocin-induced hyperglycemic animals while the extract has no effect on glucose levels in normoglycemic animals\textsuperscript{38} and also showed the analgesic activity\textsuperscript{49}. The leaf extract has been found to produce fall in blood sugar level in dogs and rats\textsuperscript{40} which may be related to anthraquinones.

The leaves of this plant are reported to contain anthraquinone compounds both free aglycones and glycosides which have laxative effect\textsuperscript{50}. Panichayupakaranant and Intaraksa (2003) demonstrated poorer quality of \textit{C. alata} leaves due to the content of hydroxyanthracene derivatives being lower than the standard value that is not less than 1.0% w/w of hydroxyanthracene derivatives, calculated as rhein-8-glucoside on a dried basis) has been a major problem in the production of the herbal medicines from \textit{C. alata}. They have studied the effect of harvesting and post-harvesting factors on the quality of \textit{C. alata} raw material and carried out analysis on the content of hydroxyanthracene derivatives of the leaves, flowers and pods of it, which had been collected at different harvesting times and different positions\textsuperscript{51}. They found that when the leaves were harvested in March, June or September, the hydroxyanthracene derivatives were accumulated more in the young and mature leaves. In December (the flowering and fruiting season), hydroxyanthracene derivatives were accumulated more in the flowers (2.21% w/w) and the pods (1.82% w/w), respectively\textsuperscript{51}. The method and temperature of drying markedly affected the hydroxyanthracene derivative content\textsuperscript{51}. Hauptmann and Lacerda-Nazário (1950) isolated rhein (Fig. 2) (1,8-dihydroxyanthraquinone-3-carboxylic acid) from alcoholic extract of \textit{C. alata} leaves by providing two different treatments (a) fractional precipitation with lead acetate and (b) by hydrolysis with sodium carbonate along with reported hydroxyl methyl anthraquinones or chrysophanic acid\textsuperscript{52}. Some known anthraquinones and its derivatives (Table 2) are also reported from roots, pods, seeds, and stems of \textit{C. alata}\textsuperscript{30,53-56}.

\textbf{Cassia angustifolia Vahl}

\textit{Cassia angustifolia} Vahl (syn. \textit{Cassia senna} Linn.) is traditionally known as Tinnevelly senna; it is a fast growing and spreading Indian shrub of which seeds, pods and leaves are extensively used for pharmaceutical applications\textsuperscript{57}. It is a reputed drug in Unani medicine, which has also been adopted by the pharmacopoeias of the world\textsuperscript{58}. It is valued as a medicine for its cathartic properties and is especially useful in habitual constipation. Its leaves and pods are traditionally used as purgatives. The main purgative constituents in the leaves are anthraquinone derivatives and their glucosides\textsuperscript{58}.

The species is widely used as a laxative, although potential side effects, such as toxicity and genotoxicity, have been reported\textsuperscript{59}. Aqueous extract of the plant produces single and double strand breaks in plasmid DNA in a cell free system\textsuperscript{59}. On the other hand, it was not cytotoxic or mutagenic to \textit{Escherichia coli} strains tested, but pointing to a new antioxidant/antimutagenic action of aqueous extract\textsuperscript{59}. Leaves of the plant are used as a safe laxative and stop bleeding\textsuperscript{60}. The active constituents of the plant are the anthranoids that are present in the leaf as dianthrones (75-80%) and as anthrones (20-25%).\textsuperscript{61} The amount of anthranoids of the emodin (Fig. 5) and aloe- emodin (Fig. 4) type is generally higher in the leaves than in the fruits\textsuperscript{61}. Leaves of \textit{C. angustifolia} also afford a significant hepatoprotective action\textsuperscript{62}.

Various anthraquinones and its glycosides (Table 2) are reported from different parts of \textit{C. angustifolia}\textsuperscript{30,36,56,58,61-68}. Mehta and Laddha (2009) had estimated amount of anthraquinone glycoside in leaves and pods of this plant. The leaves and pods of \textit{C. angustifolia} contain not less than 2.5% of anthraquinone glycosides mainly senosides A and B, that are dianthrone glucosides derived from rhein (Fig. 2) and aloe-emodin. This makes the leaf an important source of rhein, which is currently subject of interest because of its antiviral, antitumor and antioxidant properties\textsuperscript{63}. Rhein also serves as starting compound for the synthesis of diantherine (Fig. 10), which has anti inflammatory effects and is useful in osteoarthritis\textsuperscript{65}. Aqueous extracts of the leaves of \textit{C. angustifolia} is used as laxative and remedy for scabies and itching\textsuperscript{66}. Sennoside A (Fig. 11) and B (Fig. 12) also reported in seedlings of the plant and found to inhibit bovine serum monomine oxidase activity\textsuperscript{66}. Sennoside A and B content in leaves have been determined as 0.59 and 0.72%, respectively\textsuperscript{66}. El-Gengaihi \textit{et al} (1975) reported that the percentage of anthraquinone glycosides in senna decreases with the increase in area and age of leaves and pods, the decrease being sharp at maturity\textsuperscript{68}.  


Table 2 — Anthraquinone derivatives reported from *Cassia* species—Contd.

<table>
<thead>
<tr>
<th><em>Cassia</em> species</th>
<th>Plant part and reported anthraquinones</th>
<th>Ref. No.</th>
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<tbody>
<tr>
<td><em>C. absus</em></td>
<td>Roots: chrysophanol (Fig. 1), aloe-emodin (Fig. 4)</td>
<td>34</td>
</tr>
<tr>
<td><em>C. acutifolia</em></td>
<td>Root: chrysophanol (Fig. 1), physcion (Fig. 3), emodin (Fig. 5), aloe-emodin (Fig. 4), rhein (Fig. 2), sennidin C, glucorhein, chrysophancin, gluco-aloe-emodin, emodin-8-O-β-D-glucoside, Leaves &amp; pod : gluco aloe-emodin, rhein-8-monoglucoside (Fig. 6), aglycone sennidin (Fig. 7)</td>
<td>35, 36</td>
</tr>
<tr>
<td><em>C. alata</em></td>
<td>Leaves &amp; pod : gluco aloe-emodin, rhein-8-monoglucoside (Fig. 6), aglycone sennidin (Fig. 7)</td>
<td>30, 43-46, 51, 52</td>
</tr>
<tr>
<td><em>C. angustifolia</em></td>
<td>Leaves : aloe-emodin (Fig. 4), its 8-glucoside, aloe-emodin dianthraone, chrysophanol (Fig. 1), emodin 8-O-sophoroside, rhein (Fig. 2), rheum-emodin glycoside, aloe-emodin dianthraone diglucoside, sennoside A (Fig. 11), sennoside B (Fig. 12), sennoside C (Fig. 13) and sennoside D (Fig. 14), sennoside G,III,A, anthranoids of the emodin (Fig. 5) and aloe-emodin (Fig. 1), physcion (Fig. 3)</td>
<td>30, 36, 56, 61-63, 65-68</td>
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<tr>
<td><em>C. auriculata</em></td>
<td>Leaves: emodin (Fig. 5)</td>
<td>30</td>
</tr>
<tr>
<td><em>C. biflora</em></td>
<td>Flower: chrysophanol (Fig. 1), physcion (Fig. 3) and luteolin</td>
<td>83</td>
</tr>
<tr>
<td><em>C. didymobotrya</em></td>
<td>In vitro cultures: 7-acetylchrysophanol, chrysophanol-physcion-10′-10″-bianthrone Leaves: chrysophanol (Fig. 1), aloe-emodin (Fig. 4), rhein (Fig. 2)</td>
<td>85</td>
</tr>
<tr>
<td><em>C. fistula</em></td>
<td>Wood: rhein (Fig. 2), chrysophanol (Fig. 1)</td>
<td>30</td>
</tr>
<tr>
<td><em>C. grandis</em></td>
<td>Pods: fistulic acid, emodin, physcion (Fig. 3)</td>
<td>56, 87</td>
</tr>
<tr>
<td><em>C. garrettiana</em></td>
<td>Roots and roots bark: Rhamnetin-3-O-gentiobioside, emodin, chrysophanic acid fistulacin, barbaloin and rhein</td>
<td>88, 115</td>
</tr>
<tr>
<td><em>C. glauca</em></td>
<td>Heartwood: cassialoin (10-hydroxy-10-C-D-glucosylchrysophanol-9-anthrone), chrysophanol (Fig. 1), chrysophanol benzanthrone, and chrysophanol dianthrone</td>
<td>116-118</td>
</tr>
<tr>
<td><em>C. glauca</em></td>
<td>Bark: 1,8-dihydroxy-6-methoxy-3-methylanthraquinone</td>
<td>123</td>
</tr>
<tr>
<td><em>C. glauca</em></td>
<td>Stems: chrysophanol (Fig. 1) and physcion (Fig. 3), 8-hydroxy-6-methoxy-3-methylanthraquinone-1-0-α-L-rhamnopyranosyl(1→6)-β-D-glucopyranoside</td>
<td>56, 124</td>
</tr>
<tr>
<td><em>C. grandis</em></td>
<td>Pods: 1,3,4-trihydroxy-6,7,8-trimethoxy-2-methyl anthraquinone-3-O-β-D-glucopyranoside</td>
<td>129</td>
</tr>
<tr>
<td><em>C. grandis</em></td>
<td>Stems: emodin-9-anthrone</td>
<td>130</td>
</tr>
<tr>
<td><em>C. grandis</em></td>
<td>Seeds: chrysophanol (Fig. 1), 1,2,4,8-tetrahydroxy-6-methoxy-3-methylanthraquinone-2-O-β-D-glucopyranoside, 3-hydroxy-6,8-dimethoxy-2-methylanthraquinone-3-O-β-D-glucopyranoside and 1,3-dihydroxy-6,7,8-trimethoxy-2-methylanthraquinone-3-O-β-D-glucopyranoside</td>
<td>30, 56, 131</td>
</tr>
<tr>
<td><em>C. grandis</em></td>
<td>Leaves: aloe-emodin (Fig. 4)</td>
<td>125</td>
</tr>
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Contd.
Table 2 — Anthraquinone derivatives reported from Cassia species—Contd.

<table>
<thead>
<tr>
<th>Cassia species</th>
<th>Plant part and reported anthraquinones</th>
<th>Ref. No.</th>
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<tbody>
<tr>
<td>C. greggii</td>
<td>Roots: 5-hydroxy-1,4,6,7-tetramethoxy-2-methylantraquinone, 1,5,7-trihydroxy-4,6-dimethoxy-2-</td>
<td>132</td>
</tr>
<tr>
<td></td>
<td>methylanthraquinone, 5,6-dihydroxy-1,4,7-trimethoxy-2-methylantraquinone, 1-hydroxy-4,7-dimethoxy-5,6-</td>
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<tr>
<td></td>
<td>methylenedioxy-2-methylantraquinone, 5,7-dihydroxy-1,4,6-trimethoxy-2-hydroxymethylanthraquinone,</td>
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<td></td>
<td>4,5-dihydroxy-1,6,7-trimethoxy-2-methylanthraquinone, and 5,6-dihydroxy-4,7-dimethoxy-2-methylantraquinone</td>
<td></td>
</tr>
<tr>
<td>C. hirsuta</td>
<td>Seeds: 4,4′-bis(1,3,8-trihydroxy-2-methyl-6-methoxy anthraquinone) (Fig. 19)</td>
<td>136</td>
</tr>
<tr>
<td>C. italica</td>
<td>Herb: aloe-emodin (Fig. 4), chrysophanol (Fig. 1), emodin (Fig. 5), emodin rhamnoside, Physcion</td>
<td>30</td>
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<tr>
<td></td>
<td>(Fig. 3), its glucosyrlhamnoside</td>
<td></td>
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<td></td>
<td>Leaves and pods: aloe-emodin, chrysophanol, rhein (Fig. 2), sennidins A &amp; B, Sennoside A (Fig. 11) and</td>
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<td></td>
<td>B (Fig.12), 1,5-dihydroxy-3-methyl anthraquinone</td>
<td>30,67, 142</td>
</tr>
<tr>
<td>C. javanica</td>
<td>Root: emodin-8-rhamnoside; 5-hydroxyemodin-8-rhamnoside (Fig. 20), 1,3-dihydroxy-5,6,7-trimethoxy-</td>
<td>67,145</td>
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<td></td>
<td>2-methyl anthraquinone, 1,4-dihydroxy-8-methoxy-2-methylantraquinone-3-O-β-D-glucopyranoside</td>
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<td></td>
<td>Leaves: quercetin, emodin (Fig. 5) rhein (Fig. 2), chrysophanic acid, aloe-emodin (Fig. 4), chrysophanol</td>
<td>146,151</td>
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<td></td>
<td>(Fig. 1), physcion (Fig. 3) and its glucoside</td>
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<tr>
<td></td>
<td>Seeds: chrysophanol, physcion, 1,5-dihydroxy-4,7-dimethoxy-2-methylantraquinone-rhamnopyranoside,</td>
<td>30,86, 147</td>
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<td></td>
<td>1,3,6,7,8-pentahydroxy-4-methoxy-2-methylantraquinone</td>
<td>30</td>
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<td>Stem bark: 1,2-dihydro-1,3-dihydroxy6,8-dimethoxy-2-methyl-anthraquinone, 1,3,5,8-tetrahydroxy-6-</td>
<td>56,148-150</td>
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<td></td>
<td>methoxy-2-methyl-anthraquinone, 1,4,6-tetrahydroxy-5,8-dimethoxy-2-methylantraquinone,</td>
<td></td>
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<tr>
<td></td>
<td>Leaf: 1,4-dihydroxy-6,7,8-trimethoxy-2-methylanthraquinone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leaves: chrysophanol, emodin, 1,8-dihydroxy-6-methyl-3-methyl anthraquinone</td>
<td></td>
</tr>
<tr>
<td>C. kleinii</td>
<td>Aerial parts and roots: kleinixanthone-1,2,3,4</td>
<td>156,157</td>
</tr>
<tr>
<td>C. laevigata</td>
<td>Roots: physcion-8-galactoside; emodin (Fig. 5), physcion (Fig. 3)</td>
<td>163</td>
</tr>
<tr>
<td></td>
<td>Seeds: chrysophanol (Fig. 1), physcion</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Pods: physcion-8-galactoside, chrysophanol, 1,8-dihydroxy-6-methoxy-3-methyl-anthraquinone, 1-</td>
<td>30,164</td>
</tr>
<tr>
<td></td>
<td>hydroxy-6-methoxy-3-methylthrantraquinone-8-O-β-D-galactopyranoside</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leaves: physcion, 5,7′-biphysonic (floribundone 1) (Fig. 22) and 5,7′-physcion-physiciananthrone</td>
<td>165</td>
</tr>
<tr>
<td></td>
<td>(floribundone 2) (Fig. 23), chrysophanol, emodin, 1,8-dihydroxy-6-methyl-3-methyl anthraquinone</td>
<td></td>
</tr>
<tr>
<td>C. marginata</td>
<td>Seeds: chrysophanol (Fig. 1), physcion (Fig. 3), 1,3-dihydroxy-2-methylanthraquinone-8-O-α-L-</td>
<td>30,169, 170</td>
</tr>
<tr>
<td></td>
<td>arabinopyranoside, 1,3-dihydroxy-6-8-dimethoxy-2-isoprenylantraquinone, 8-O-α-L-xylpyranoside, 2-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stem bark: 1,2-dihydroxyanthraquinone-1,2,3,4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roots: 4,4′-bis(1,3,8-dimethoxy-2-methylantraquinone-3-O-β-D-glucopyranosyl)</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Flower:1,8-dihydroxy-3-carbo(β-D-glucopyranosyl) anthraquinone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leaves: 1,2-dihydroanthraquinone, roxburghinol, chrysophanol, physcion, rhein (Fig. 2)</td>
<td>172</td>
</tr>
<tr>
<td></td>
<td>Wood: roxburghinol, chrysophanol</td>
<td></td>
</tr>
<tr>
<td>C. mimosoides</td>
<td>Leaves: emodin (Fig. 5), its glycoside Root: physcion (Fig. 3)</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Seeds: emodin, emodic acid, physcion</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Aerial parts: chrysophanol (Fig. 1), 1,8-dihydroxy-6-methoxy-2-methylantraquinone (Fig. 28)</td>
<td>30, 173</td>
</tr>
<tr>
<td>C. multijuga</td>
<td>Seeds: 1,3,8-trihydroxy-2-methyl anthraquinone, 1,3-dihydroxy 6,8-dimethoxy-2-methyl anthraquinone,</td>
<td>174</td>
</tr>
<tr>
<td></td>
<td>3-hydroxy-6,8-dimethoxy-2-methyl anthraquinone-1-O-β-D(-) glucopyranoside and 3-hydroxy-6,8-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6,8-dimethoxy-2-methyl anthraquinone-1-O-β-D-galactopyranosyl (rutinoside)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roots: 1,3-dihydroxy-2-methyl anthraquinone, 1,3-dihydroxy 6,8-dimethoxy-2-methyl anthraquinone,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,3,8-trihydroxy-6-methoxy-2-methyl anthraquinone, 1,8-dihydroxy-8-methoxy-2-methylanthraquinone-3-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>O-rutinoside, 1-hydroxy-6,8-dimethoxy-2-methylanthraquinone-3-O- rutinoside, 1,8-dihydroxy-6-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. nigricans</td>
<td>Whole plant: 1,3,8-trihydroxy-6-methyl-9,10-anthracenedione, 4-hydroxy-anthraquinone-2-carboxylic</td>
<td>176,178</td>
</tr>
<tr>
<td></td>
<td>acid (Fig. 29)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leaves: emodin (Fig. 5), citreorosein (Fig. 30) and emodic acid (Fig. 31)</td>
<td>179,180</td>
</tr>
<tr>
<td></td>
<td>Leaves &amp; pods: Emodin, emodin-9-anthrone, and physic 10,10-bianthraione</td>
<td>30</td>
</tr>
<tr>
<td>C. nomame</td>
<td>Seeded: Physcion (Fig. 3), physic-9-anthrone, emodin-9-anthrone, and physic 10,10-bianthraione</td>
<td>182</td>
</tr>
<tr>
<td></td>
<td>Aerial parts: chrysophanol (Fig. 1), and physcion (Fig. 5)</td>
<td></td>
</tr>
<tr>
<td>C. obtusa</td>
<td>Roots: 1-3-dihydroxy-6-methoxy-7-methylanthraquinone and 1,3-dihydroxy-3,7-diformylanthraquinone</td>
<td>184</td>
</tr>
<tr>
<td>C. obtusifolia</td>
<td>Seeds: aloe-emodin (Fig. 4), 1-methylaurantio-obtusin-2-O-β-D-glucopyranoside, emodin (Fig. 5), 1,2-</td>
<td>30,36, 67,191,193-202</td>
</tr>
<tr>
<td></td>
<td>dihydroxyanthraquinone, obtusin, chrysoobtusin, aurantioobtusin, gluco-obtusifolin, gluco-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>aurantioobtusin, gluco-chryso-obtusin, 1-desmethylaurantio-obtusin, 1-desmethylaurantio-obtusin-2-O-β-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D-glucopyranoside, 1-desmethylychryso-obtusin, 1-desmethyl-obtusin, aurantio-obtusin-6-O-β-D-</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>Contd.</td>
<td></td>
</tr>
<tr>
<td>Cassia species</td>
<td>Plant part and reported anthraquinones</td>
<td>Ref. No.</td>
</tr>
<tr>
<td>----------------</td>
<td>------------------------------------------------------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>C. podocarpa</td>
<td>Leaves: emodin, senna A (Fig. 11) &amp; senna B (Fig. 12)</td>
<td>30,219-221</td>
</tr>
<tr>
<td></td>
<td>Pods: rhein &amp; its glucoside, rhein-anthroneglucoside, senna A &amp; senna B</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Callus culture: rhein and chrysophanol</td>
<td>31</td>
</tr>
<tr>
<td>C. pudibunda</td>
<td>Roots: chrysophanol dimethyl ether, chrysophanol (Fig. 1), physcion (Fig. 3), sennosides</td>
<td>30,224</td>
</tr>
<tr>
<td>C. pumila</td>
<td>Whole Plant: emodin (Fig. 5), physcion (Fig. 1), sennosides</td>
<td>30,224</td>
</tr>
<tr>
<td>C. racemosa</td>
<td>Stem bark: racemochryson (Fig. 34), physcion (Fig. 1), physcion (Fig. 3)</td>
<td>225,226</td>
</tr>
<tr>
<td>C. reticulata</td>
<td>Leaves: emodin (Fig. 1), physcion (Fig. 3), rhein (Fig. 2)</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Stem bark: 1-hydroxy-3,8-dimethoxy-2-methylanthraquinone, 1,5,6-di hydroxy-3-methyl-anthraquinone-8-O-α-L-glucoside</td>
<td>30,227</td>
</tr>
<tr>
<td>C. siamea</td>
<td>Leaves: cassiamin A (Fig. 35), chrysophanol (Fig. 1), physcion (Fig. 3), rhein (Fig. 2), sennosides</td>
<td>30</td>
</tr>
<tr>
<td>C. sophera</td>
<td>Leaves: senna A; Flower: chrysophanol (Fig. 1)</td>
<td>30</td>
</tr>
<tr>
<td>C. spectabilis</td>
<td>Leaves: chrysophanol (Fig. 1), physcion (Fig. 3), 1,3,8-trihydroxy-2-methylanthraquinone</td>
<td>30</td>
</tr>
<tr>
<td>C. tomentosa</td>
<td>Whole plant: senguolute (Fig. 37), emodin (Fig. 5), floribundone (Fig. 1)</td>
<td>56</td>
</tr>
<tr>
<td>C. toma</td>
<td>Seeds: Chryssoptusin, aurantio-obtusin, obtusin, chryso-obtusin-2-O-β-D-glucoside, physcion (Fig. 3),</td>
<td>30,248, 271-276</td>
</tr>
<tr>
<td></td>
<td>emodin, chrysophanol, and obtusolfin-2-O-β-D-glucoside, rhein (Fig. 2), 1-methylaurantio-obtusin, 1-methylchryso-obtusin, 1-{[β-d-glucopyranosyl-(1→3)-O-β-d-glucopyranosyl-(1→6)-O-β-d-glucopyranosyl]oxyl}-8-hydroxy-3-methyl-9,10-anthraquinone, 1-{[β-d-glucopyranosyl-}</td>
<td>269, 271-276</td>
</tr>
</tbody>
</table>

Contd.
Cassia species | Plant part and reported anthraquinones | Ref. No.
---|---|---
*C. torosa* | (1→6)-O-β-d-glucopyranosyl-(1→3)-O-β-d-glucopyranosyl-(1→6)-O-β-d-glucopyranosyl(oxy)-8-hydroxy-3-methyl-9,10-anthraquinone and 2-(β-d-glucopyranosyloxy)-8-hydroxy-3-methyl-1-methoxy-9,10-anthraquinone, alaternin 2-O-β-d-glucopyranoside, alaternin, aloe-emodin (Fig. 4), chrysophanic acid & its 9-antron, 8-hydroxy-3-methylanthraquinone-1-β-gentiobiose, rubrofusarin & its 6-β-gentiobiose, nor-rubrofusarin, torachrysonone. Leaves: aloe-emodin, 1,8-dihydroxy-3-hydroxymethylanthraquinone, emodin (Fig. 5). Roots: 1,3,5-trihydroxy-6,7-dimethoxy-2-methylanthaquinone 30,270, 30,277. Stem: rhein (Fig. 2), 1-hydroxy-5-methoxy-2-methyl anthraquinone & its glycoside, 5-methoxy-2-methylanthraquinone-1-O-α-L-rhamnoside. Chrysophanol, emodin (Fig. 5). | 30 |
*C. torosa* | Seedlings: phlegmacin, anhydrophlegmacin-9,10-quino, germichryson, germitosone, 278,279,281 methylgermitorosone 280,282,283. Seeds: Torosachrysone, phycion-9-antron, physcion-10,10'-bianthrone, anhydrophlegmacinB, [2-(6'-methoxy-3'-methyl-3',8',9'-trihydroxy-1'-o xo-1',2',3',4'-tetrahydroanthracene-10'-yl)-1,8-dihydroxy-3'- methoxy-6-methyl-9-oxo-9,10-dihydroanthracene] and torosanin [2-(6'-methoxy-3'-methyl-3',8',9'-trihydroxy-1'-oxo-1',2',3',4'-tetrahydroanthracene-5'-yl)-1,8-dihydroxy-3'-methoxy-6-methyl-9-oxo-9,10'- dihydroanthracene], torosachrysone 8-β-D-gentiobiose, physcion 8-β-D-gentiobiose, physcion (Fig. 3), xanthorin and emodin (Fig. 5). | 285 |
*C. auriculata* | Flowers: torosaol-III, physcion, 5,7'-physcionanthrone-physcion, 5,7'-biphyscion, torosanin-9,10-quinone, 5,7-dihydroxy-chromone, naringenin, chrysoeriol and methanol extracts of flowers showed antioxidant activity. The leaf extract has potential to reduce the liver injury caused by alcohol. Supplementation with leaf extract can offer protection against free radical mediated oxidative stress in experimental hepatotoxicity. In addition, histopathological studies of the liver and brain confirmed the beneficial role of leaf extract. *C. auriculata* tea has the potential to influence the bioavailability of carbamazepine, and hence its therapeutic actions. In folk remedies of India, its flowers are proposed to have antidiabetic activity. Leaves of *C. auriculata* are having potential in the development of drug for diabetes due to its antihyperglycemic and lipid-lowering activity. *C. auriculata* exerts a strong antihyperglycemic effect in rats comparable to the therapeutic drug Acarbose. Aqueous leaf extract was found to lower the serum glucose level, and also found to inhibit the body weight reduction induced by alloxan administration. The ethanolic extract had nephroprotective effect and the probable mechanism of nephroprotection by *C. auriculata* against cisplatin and gentamicin induced renal injury could be due to its antioxidant and free-radical-scavenging property. and methanol extracts of flowers showed antioxidant activity. | 284,286 |
*C. biflora* Linn. | It is a medium size shrub which flowers profusely. Hemlata and Kalidhar (1995) reported presence of chrysophanol (Fig. 1), physcion (Fig. 3) and luteolin in the plant.
**Cassia didymobotrya** Fresen.

It is a evergreen shrub, native to East Africa. It can tolerate full sun and grows with little water. A 23-kDa thauamatin-like protein isolated and purified from *C. didymobotrya* cell cultures shown antifungal activity.

Presence of chrysophanol (Fig. 1) along with various anthraquinones (Table 2) is reported from different parts of this species.

**Cassia fistula** Linn.

*Cassia fistula* Linn. (Hindi-Amaltas, English-Golden shower, Indian Labernum and Lantern tree in Thailand) is a semi-wild slender tree, with moderate to fast growth. It is a native of India, the Amazon and Sri Lanka and extensively diffused in various countries including Mauritius, South Africa, Mexico, China, West Indies, East Arica and Brazil as an ornamental plant and widely cultivated as an ornamental tree for its beautiful bunches of yellow flowers. It is highly reputed for its strong laxative and purgative properties. In Ayurvedic medicine, it is used against various disorders such as haematemesis, puritus, leucoderma and diabetes. The antipyretic, analgesic effect of *C. fistula* has also been reported, together with its antifungal, antibacterial and anti-inflammatory activities. The plant extract is also recommended as a pest control agent. These effects have been mainly attributed to the presence of alkaloids, triterpene derivatives, anthraquinone derivatives, and polyphenolics comprising flavonoids, catechins and proanthocyanidins.

Different parts of the plant have been demonstrated to possess several medicinal values such as antitumor, antioxidant and hypoglycemic activities. In Thai traditional medicines, the ripe pods have been used as a laxative drug by boiling with water and the mixture is filtered through a muslin cloth. The filtrate is evaporated and the soft extract is made as small pills.

*C. fistula* is an important constituent in the traditional medicine in India and possesses properties useful in the treatment of inflammatory diseases, skin diseases, rheumatism, ulcers, anorexia, jaundice, and as laxatives. Root of the tree is also used as a laxative, useful in fever, heart disease, retained excretions, biliousness, etc. The pulp of fruits of *C. fistula* is lenitive, useful for relieving thoracic obstructions and heat of blood and is a safe aperient for children and women. The leaves are also found effective against cough and ringworm infections. The active principles are known to be anthraquinone glycosides of which rhein, sennoside and aloe-edomin are major components. Extensive studies have been carried out during the past few decades on isolation and characterisation of anthraquinones (Table 2) from various parts of the species. The anthraquinone glycosides remain high in the mature and old leaves in the months from January to April when the contents of mature pods are low. In the developing green pods the content is high compared to the older ones, while the young leaves have lower glycosidal content compared to their mature stage.

**Cassia garrettiana** Craib

*Cassia garrettiana* Craib, known in Thai as Samaesarn, is a small tree, up to 10 m high with alternate even-pinnate, leaves. In Thai traditional medicine, the heartwood of this plant is used to cure feminine diseases and as blood tonic for women. *C. garrettiana* has been reported to show many biological activities such as anticancer, antifungal, acid secretion inhibitor, anti-allergy and antihypertensive activities, and used as mild cathartics. The heartwood of the plant with above mentioned properties afford a new anthrone-c-glycoside named cassialoin (10-hydroxy-10-C-D-glucosylcrysophanol-9-anthrone) together with other anthraquinones (Table 2) as well as various phenolic compounds. Cassialoin (5 and 10 mg/kg) inhibited tumor growth and metastasis to the abdomen and the expression of CD31 (angiogenesis marker) in the tumors, and it increased the numbers of the γ-interferon (IFN-γ)-positive, CD8⁺T and natural killer cells in the small intestine or spleen of colon 26-bearing mice. Furthermore, cassialoin inhibited tumor-induced angiogenesis in colon 26-packed chamber-bearing mice. These antitumor and antimetastatic actions of cassialoin may be partly due to cassialoin and its metabolites such as chrysophanol-9-anthrone and aloe-edomin through their anti-angiogenic activities and/or the modulation of the immune systems in the spleen and small intestine in tumor-bearing mice.

*C. garrettiana* was investigated for its active constituents against HIV-1 protease (HIV-1 PR). Tewtrakul et al (2007) carried out bioassay-guided fractionation of the heartwood of this plant which led to the isolation of a stilbene derivative piceatannol and an anthraquinone derivative chrysophanol. This pigment showed significant HIV-1 protease inhibitory activity whereas its related anthraquinone derivatives emodin, aloe-edomin and rhein were inactive.
Cassia glauca Lam.

Cassia glauca Lam. (syn. Cassia surattensis Burm. f.) is an evergreen shrub that grows about 3 m high with ovate, pointed leaflet. Aerial parts of the plant are used as a central nervous system depressant, purgative, antimalarial and as a diuretic. The bark and leaves have been used in diabetes for lowering blood glucose level and gonorrhea in the Ayurvedic system of medicine. Acetone extract of C. glauca shows significant antidiabetic activity while C. glauca bark extracts have hypoglycemic potential of ameliorating the diabetic conditions in diabetic rats. The phytochemical investigation of plant shows the presence of γ-sitosterol, fatty acids, anthraquinones, tannis, and alkaloids and a water soluble biopolymer composed of D-galactose and D-mannose in molar ratio 1:3. Anthraquinones (Table 2) have been isolated and characterized from bark and stem whereas Gritsanapan and Nualkaew (2002) estimated the content of total anthraquinone glycosides and total anthraquinones in the leaves using UV-spectrophotometric method and reported 0.02-0.03% and 0.03-0.06% (dry wt), respectively. The variation of both anthraquinone glycosides and total anthraquinones in the leaves collected from several areas and seasons were not significantly different. The content of emodin, a major anthraquinone from glycosidic fraction, was 0.0003-0.0017% dry weight when determined by TLC densitometric method.

Cassia grandis Linn f.

Cassia grandis Linn f. known as Coral shower, Apple blossom cassia, Pink shower, Liquorice tree or Horse cassia is a medium-sized tree, up to 20-30 m tall, found in abundance throughout India. Its seeds contain about 50% endosperm gum and possess the characteristics of becoming a potential source of seed gum. The ethanol extract of the leaves and bark showed in vitro antifungal activity against Epidermophyton floccosum, Microsporum gypseum and Trichophyton rubrum in pure culture at a minimal inhibitory concentration of 50 µg/ml. This plant has significant anti-inflammatory and analgesic properties. Anthraquinones (Table 2) are reported from its stem, pods and seeds. Due to presence of anthraquinones it is especially used as a purgative in veterinary practice.

Cassia greggii Gray

Cassia greggii Gray is a small tree having 3-5-foliate 1cm long leaves and leaflets oblong-oval, slightly truncate. González et al. (1992) have isolated seven new anthraquinones (Table 2) from the dichloromethane extract of its roots. Their structures were elucidated on the basis of spectral data.

Cassia hirsuta Linn. syn. Senna hirsuta (Linn.) H.S. Irwin & Barney

A diffuse shrub widely distributed in the hilly tracts of South India. C. hirsuta, commonly known as ‘Stinking cassia’ is used for the local treatment of liver ailments and is an important ingredient of polyherbal formulations marketed for liver diseases. The main effects of the C. hirsuta leaves extract could be both preventive and therapeutic. Ethanolic leaf extract has significant hepatoprotective effect, and used for stomach troubles, dysentery, abscesses, rheumatism, haematuria, fever and other diseases. The ethanol extract of leaf was also found to have antimicrobial activity against some pathogenic bacteria. The seeds contain a phytotoxin, tannin and 0.25% chrysarobin. Singh and Singh (1986) reported that seeds contain a new bianthraquinone, 4,4′-bis(1,3,8-trihydroxy-6-methoxy-2-methyl) anthraquinone (Fig. 19) and a triterpenoid 3β,16β,22-trihydroxyisohopane.

Cassia italica (Mill.) Lam. ex F.W. Ander

Cassia italica (Mill.) Lam. ex F.W. Ander (syn. Cassia obovata Collad.) is a small shrub, with 3-12 cm long leaves, with petiole and rachis eglandular. It is used for the production of folioles from which sennosides can be extracted and used in traditional medicine for the treatment of diverse ailments. C. italica is also a rich source of flavonoids and sennoside A (Fig. 11) and B (Fig. 12) (Table 2) were isolated from its leaves and pods.

The ethanolic extract of the whole plant parts (root, stem leaves and pods) of C. italica was investigated for bioactivities namely anti-inflammatory, antipyretic, analgesic, prostaglandin (PG) release by rat peritoneal leukocytes, antineoplastic and antiviral activities. In rats, the extracts reduced carrageenan-induced paw swelling (100 mg/kg bw-31%) and fever (100 mg/kg bw-37%). The extract showed weak effects on writhing induced by acetic acid. A dose-dependent inhibition of PG release effect was observed using rat peritoneal leukocytes. Extracts of various parts were found to contain antimicrobial activity and crude ethanolic extract has CNS depressant properties, manifested as antimisception and sedation. Kazmí et al. (1994) carried out phytochemical studies of the leaves and reported 1,5-dihydroxy-3-methyl anthraquinone and an anthraquinone (Table 2) that possess antimicrobial and antitumour activities.
Cassia javanica Linn. syn. Cassia nodosa Buch-Ham. ex Roxb.
A small to medium-sized tree up to 25-40 m tall, deciduous or semi-deciduous, trunk of young trees either smooth or armed with stump-remnants of branches. The flowers are good source of flavonoid glycosides. The seed gum of C. javanica has rheological property. Purgative nature and haemagglutinating activity of seed extracts are main reported application of C. javanica, however phytochemical analysis of various parts of this plant reported presence of usual and novel anthraquinones (Table 2). A new compound, nodolidate, has been isolated from the flowers and characterized as (-)-7-acetoxy-9,10-dimethyl-1,5-octacosanolide. Nodososide, also naturally occurs in its flowers.

Cassia kleinii White & Arn.
Cassia kleinii White & Arn. is a diffused under-shrub found in partly shaded and moist places. The alcohol extract of leaf exhibited concentration dependent antihyperglycemic effect in glucose loaded rats. But the extract did not show hypoglycemic effect in fasted normal rats. Various oxanthrone esters are reported from all the parts of this plant reported presence of usual and novel anthraquinones (Table 2). A new compound, nodolidate, has been isolated from the flowers and characterized as (-)-7-acetoxy-9,10-dimethyl-1,5-octacosanolide. Nodososide, also naturally occurs in its flowers.

Cassia laevigata Willd. syn. Cassia floribunda Cav.
A shrub of 2-3 m high with yellow flowers and pinnate leaves consisting of three or four pairs of ovate leaflets. Leaves and branches are found to contain unusual fatty acids and flavonoids. The seeds are found to be an important under-utilized legume seeds served as low-cost protein sources to alleviate the protein-energy-malnutrition among people living in developing countries. However purgative antherquinones along with some new antherquinones (Table 2) reported from all the parts of C. laevigata including seeds.

Cassia marginata Linn.
Cassia marginata Linn. (syn. Cassia roxburghii DC.) known as ‘Red Cassia’ is smaller and less robust than the other species, but is extremely beautiful at all times of the year. This is a large sized Indian tree having cylindrical and indehiscent long pods (with many seeds) containing a black cathartic pulp, used as a horse medicine. Seeds are medium in size and consist of about 50% endosperm which is responsible for yielding water soluble gum. Seed gum (8%) could be useful as binding agent especially when high mechanical strength and slower release is concerned. Various anthraquinone and its derivatives (Table 2) are reported from all the parts.

Cassia mimosoides Linn.
Cassia mimosoides Linn. (Karagain), Chiang-Mang (in Chinese.) is a low, diffuse shrub up to 1.5 m in height found in open grasslands at low and medium altitudes, in some regions ascending to 1,500 m. The roots are used as cure for diarrhoea. The young stems and leaves are dried and used as a substitute for tea in Japan. All the parts are found to contain anthraquinones (Table 2) along with 1,8-dihydroxy-6-methoxy-2-methyl anthraquinone (Fig. 28) and 1,8-dihydroxy-6-methoxy-3-methyl anthraquinone (Fig. 29) are reported from the aerial parts.

Cassia multijuga Rich.
Cassia multijuga Rich. (Leafy cassia) is a medium sized legume tree, 10 to 15 m in height that frequently occurs in secondary forests, clearings, edges, regeneration areas and pastures. Leaves are used as a sedative for children. Seeds of this plant are used as a source of industrial gum. Seeds and roots contain anthraquinones and some new derivatives (Table 2) are also isolated which are not reported from any other plant source.

Cassia nigricans Vahl
It is a herbaceous plant, apparently annual, erect, simple or branched woody herb or undershrub up to 1.2 -1.5 m high with small yellow flowers that grow widely in the savannah grasslands of West Africa including Nigeria. The roots and leaves have been used medicinally in Senegal and Guinea as a substitute for quinine for many years. The root infusion is also used as a vermifuge. The pulverized leaves are employed as appetizers and febrifuge, while the leaf decoction is used in treating fevers. It is widely used for treating skin diseases such as ringworm, scabies and eczema. The aqueous extract of the leaves is used by traditional healers in Nigeria for the treatment of peptic ulcer and other gastrointestinal disorders, beside this extract is found to show analgesic and anti-inflammatory effects. A pinch of the grounded leaves is taken with water for the treatment of peptic ulcers. The methanolic extract of leaves found to have antidiarrhoal effect might be due to α2-adrenergocetor stimulation. The extract also reduced significantly the ulcers induced by both indomethacin and ethanol.
The methanolic extract also shown in vitro antiplasmodial activity against \( P. \) \textit{falciparum} strain. This finding supports the traditional use of the plant for the treatment of malaria\[178\]. It is commonly used in West Africa to protect grain storage from insects\[179\] which is reported due to the presence of anthraquinones in the plant (Table 2)\[30,176,178-180\].

Anthraquinones isolated from crude extract of this plant are the main anti-plasmodial principle and also have potential analgesic and anti-inflammatory activity\[176,178\]. Anthraquinones emodin (Fig. 5), citreorosein (Fig. 30) and emodic acid (Fig. 31) were isolated as insecticidal principles. Emodin, the most abundant and active anthraquinone showed about 85\% mortality on mosquito larvae of \textit{Anopheles gambiae}a and adult \textit{B. tabaci} at 50 and 25 \text{lg/ml}, respectively, in 24 h, therefore the extract of \textit{C. nigricans} has the potential to be used as an organic approach to manage some of the agricultural pests\[179\]. Emodin isolated from the ethyl acetate extract of the leaves showed significant antimicrobial activity on some common pathogens\[180\]. The isolation of the emodin justifies the use of its leaves in herbal medicine for the treatment of skin diseases and gastro-intestinal disorders\[180\].

\textbf{Cassia nomame (Sieb.) Honda}

It is native to China and originally reported in the South of the Changjiang River. \textit{C. nomame} extract is widely used as health food supplements, pharmaceuticals and in cosmetic preparation. It is a new source in the natural product industry to help people with weight problems by using its lipase inhibition activity to prevent the fat absorption. The aqueous extract from leaves, stems and pods called “Hama-cha” is a conventional beverage in the San-in district of Japan\[181\]. It is also used as a raw material for a diuretic or antidote in a folk remedy\[181\]. The extract has suppressing effect on clastogenicity and cytotoxicity of mitomycin C in CHO Cells\[181\]. Kitanaka and Takido (1985) concluded that the seeds and aerial parts of \textit{C. nomame} are found to contain various anthraquinones (Table 2)\[182\].

\textbf{Cassia obtusa Linn.}

The species consist of small herbs found in tropical and subtropical regions and have wide applications in herbal formulations. Leaf, stem and fruits are used to cure various ailments in human beings. It produces a diverse range of bioactive molecules including anthraquinones (Table 2); making them a rich source of different types of medicines\[183,184\]. It was observed that aqueous, benzene and methanol extracts of fruit exhibited inhibitory action against wide range of bacteria including Gram negative bacteria\[183\].

\textbf{Cassia obtusifolia Linn.}

\textit{Cassia obtusifolia} Linn. (Sicklepod) is an annual weed with erect, nearly hairless stems. The plant and its seeds are common contaminants of agricultural commodities, are toxic to cattle and poultry. Toxicity has been attributed to anthraquinones which are major constituents of the plant\[185\]. The composition of Sicklepod seed has been reported to include anthraquinones, 1-2; fats, 5-7; proteins, 14-19; and carbohydrates, 66-69\%\[Ref. 186\]. Sicklepod seed contains a gum of commercial interest in addition to protein and fat\[187\]. As much as 41\% of the seed was extractable\[188\]. Some extracts were strong inhibitors of wheat, velvetleaf and sicklepod root growth, causing discoloration of the root meristems in a manner similar to that caused by naphthoquinones such as juglone and plumbagin\[188\]. Some extracts increased weight gain in fall armyworm (\textit{Spodoptera frugiperda}) causing them to grow to 50-100\% larger than controls in a 7-day trial\[188\]. Naturally occurring quinones and quinone-containing extracts of seeds affected muscle mitochondrial function\[189\]. Ethanolic extract of the seeds has neuroprotective effects\[190\].

Juemingzi (seeds of \textit{C. obtusifolia}) is a reputed laxative and tonic in Chinese medicine\[191\] and has been widely used in traditional Chinese medicine for treatment of red and tearing eyes, headache and dizziness\[192\]. The herb is traditionally used to improve visual acuity and to remove “heat” from the liver and currently also used to treat hypercholesterolemia and hypertension\[193\]. Li \textit{et al} (2004) reported antiseptic, diuretic, diarrhoeal, antioxidant and antimutagenic activities of \textit{C. obtusifolia}\[194\]. Presence of various anthraquinone derivatives in seeds (Table 2) impart above mentioned pharmacological properties, however anthraquinones are also reported from root (Table 2)\[30,36,67,191-203\]. It has been reported and confirmed that among 25 leguminous seeds, the methanol extract of \textit{C. obtusifolia} and \textit{C. tora} seeds exhibit a potent larvicidal activity against \textit{A. aegypti} and \textit{C. pipiens pallens}\[195\]. Yang \textit{et al} (2003) studied mosquito larvicidal activity of \textit{C. obtusifolia} seed-derived materials and the biologically active component of seeds was characterized as emodin (Fig. 5) using spectroscopic analysis\[196\]. 1,2-Dihydroxyanthraquinone isolated from seeds strongly
inhibit the growth of *Clostridium perfringens* and *Escherichia coli*. Structure-activity relationship revealed that 1,4-dihydroxyanthraquinone and 1,8-dihydroxyanthraquinone has strong growth-inhibition against *C. perfringens*. In growth-promoting activity, 1,2-, 1,4-, and 1,8-dihydroxyanthraquinones exhibited strong growth-promoting activity to *Bifidobacterium bifidum*59. Yun-Choi et al (1990) found three anthraquinone glycosides, gluco-obtusifolin, gluco-chryso-obtusin and gluco-aurantiobtusin, to be platelet anti-aggregatory constituents of seeds of *C. obtusifolia*79. Guo et al (1998) investigated anthraquinone production in hairy root cultures of *C. obtusifolia* clones transformed with *Agrobacterium rhizogenes* strain 9402. The effects of culture conditions and rare earth element Eu\(^{3+}\) on the production of six free anthraquinones have also been investigated. It was found that changes of the elements in the culture medium and addition of rare earth element Eu\(^{3+}\) can greatly influence the contents of free anthraquinones in the hairy roots191.

**Cassia occidentalis** Linn.

* Cassia occidentalis* Linn. also known as Coffee Senna, Stink Weed, Stinking or Negro Coffee and Kasaundi in India. The leaves and flowers of *C. occidentalis* can be cooked and are edible. It has been reported that the infusion of the leaves is used as an effective treatment for hepatitis204. *C. occidentalis* has long been used as natural medicine in rainforests and other tropical regions for the treatment of inflammation, fever, liver disorders, constipation, worms, fungal infections, ulcers, respiratory infections, snakebite and as a potent abortifacient205. In Senegal, the leaves of *C. occidentalis* are used to protect cowpea seeds, *Vigna unguiculata* Linn. (Walpers) against *Callosobruchus maculatus* (Coleoptera: Bruchidae). Both fresh and dry leaves as well as whole and ground seeds had no contact toxicity on the cowpea beetle206. In contrast, seed oil induced an increase in mortality of *C. maculatus* eggs and first larval instar at the concentration of 10 ml/kg cowpea206. *C. occidentalis* was proved to be toxic to heifers with the more prominent clinical symptoms depressed muscular tone, weakness and slow march that evolutioned in few days until prostration207. The gum derived from seed endosperm can be potentially utilized in a number of industries to replace the conventional gums208. The seeds are bitter and used for winter cough and as a cure of convulsion in children209. Seeds are commonly used in West Africa to prepare a beverage which serves as a substitute for coffee209. The plant possesses antimutagenic activity against benzo[α]pyrene (BaP) and cyclophosphamide (CP)-induced mutagenicity210. It is also found that it modulated hepatic drug metabolizing enzymes. It is suggested that by a similar mechanism, it may be influencing the hematoxic and immunotoxic responses of cyclophosphamide210. *C. occidentalis* is used in Unani medicine for liver ailments and is an important ingredient of several polyherbal formulations marketed for liver diseases. The aqueous-ethanolic extract (50%, v/v) of leaves of the plant produced significant hepatoprotection211,212. This weed has been known to possess antibacterial, antifungal, anti-diabetic, anti-inflammatory, anticancerous, antimutagenic and hepatoprotective activity213. Yadav et al (2009) mentioned about wide range of chemical compounds including achoasin, aloe-emodon (Fig. 4), emodon (Fig. 5), anthraquinones, anthrones, apigenin, aurantiobtusin, campesterol, cassiolidin, chryso-obtusin, chrysophanol (Fig. 1), chrysoeriol, etc. from this plant214. Anthraquinone derivatives reported mainly from leaves, seeds and roots (Table 2) of *C. occidentalis*33,37,68,214-217. Chukwujekwu et al (2006) examined the antibacterial activity of the ethanolic root extract and isolated and identified biologically active component as emodin by spectroscopic analysis215. Root of the plant contains 4.5% anthraquinone of which 1.9% are free anthraquinones which include 1,8 dihydroxy anthraquinone, emodon, quercetin and a substance similar to rhein (Fig. 2)216.

**Cassia podocarpa** Guill. & Perr.

It is a commonly grown shrub on old farmland, mainly in forest regions of West Africa and is closely related to recognized “senna”, its leaves and fruits are mentioned as purgatives217. The decoction of the leaves, roots and flowers is given for the treatment of venereal diseases in women217. Fresh leaves are grounded and applied as poultices to the swellings, wounds and used both internally and externally for skin diseases and yaws217. For headache, they are rubbed on the forehead and temples and a lotion is made from them for opthalmia217. With proper processing leaves can be substituted for *C. acutifolia* leaves as a vegetative laxative217. Like many other members of the genus *C. podocarpa* contains anthraquinone derivatives, responsible for the laxative
properties. The main constituents responsible for above mentioned properties are the anthraquinone glycosides; however the anthraquinone glycosides of C. podocarpa leaf and C. acutifolia are not likely to be the same. Rai (1988) carried out an analytical investigation of callus tissues from seedlings of C. podocarpa grown on Murashige and Skoog agar medium and demonstrated the presence of number of hydroxyl anthraquinone compounds including rhein (Fig. 2) and chrysophanol (Fig. 1).

 Constituents of the leaves and pods of C. podocarpa that have been identified include rhein, emodin (Fig. 5), chrysophanol (Table 2) and other combined and free anthraquinones. The study of seasonal variations and spectrophotometric determination of anthraquinones in cultivated C. podocarpa showed that combined anthraquinones were concentrated in the leaves at peak flowering (2.43%) while the bark had lowest value (0.21%). Anthraquinone glycosides reached peak levels during the months of October to March (dry season), the glycosidsic content during the rainy season which may be due to interconversion of some glycosides to the aglycones. During the rainy season which may be due to interconversion of some glycosides to the aglycones. The inclusion of C. podocarpa in the African Pharmacopoeia will no doubt enhance its commercialization as laxative and for its antimicrobial effect.

Cassia pudibunda Benth.
It is a shrubby plant. Messana et al (1991) isolated the new naphthopyrone rubrofusarin-6-O-β-D-glucopyranoside, quinquangulin-6-O-β-D-apiofuranosyl-(1→6)-O-β-D-glucopyranoside, quin-quangulin-6-O-β-D-glucopyranoside and chrysophanol dimethyl ether by chemical examination of the methanolic extract of the stem bark along with sennosides A, B and C. The study showed papaverine like, non-specific spasmylocytic activity on isolated ileum of guinea pig. Shade dried and coarsely powdered plant material when subjected to sequential solvent extraction in Soxhlet extractor successively using petroleum ether, benzene, acetone, chloroform, alcohol and distilled water shown presence of anthraquinones in aqueous extract, while sennosides was detected in all other extracts.

Cassia racemosa Mill. syn. Senna racemosa (Mill.) H.S. Irwin & Barneby
 It is a widely distributed species in Mexico. It is used in traditional indigenous medicine against diarrhea and eye infections. Mena-Rejón et al (2002) reported a new dihydroanthracenone derivative, named racemochrysone (Fig. 34) (Table 2) from the hexane extract of the stem bark along with chrysophanol and physcion. Methanol extracts of leaves, roots and bark are reported to have good antiprotozoal activity against Giardia intestinalis and Entamoeba histolytica. Extracts from stem bark and leaves were most active, with an IC50 of 2.10 μg/ml for G. intestinalis and 3.87 μg/ml for E. histolytica. Of the previously reported compounds by Mena-Rejón et al (2002) chrysophanol (Fig. 1), a 1,8-dihydroxy-anthraquinone, was the most active agent against E. histolytica, with an IC50 of 6.21 μg/ml.

Cassia renigera Wall. ex Benth.
Cassia renigera Wall. ex Benth., known as Burmese pink cassia is a typical tropical tree that grows to height of up to 10 m, spreads foliage rich branches to all sides. It is known as rich source of anthraquinones and flavonoids (Table 2). Ledwani and Singh (2005) reported 1,5,6-trihydroxy-3-methyl–anthraquinone-8-O-α-L-glucoside from the bark and its structure elucidated with the help of chemical studies and spectral data. They studied dyeing property of crude anthraquinone to develop variety of shades on wool by using different methods.

Cassia reticulata Wild.
Cassia reticulata Wild. [syn. Senna reticulata (Willd.) H. S. Irwin & Barneby] commonly known as
Golden Lantern tree is a beautiful flowering small tree whose branches spread out in most dignified manner with exquisite dense, pale-green leaves. Extracts of the plant inhibit the growth of some microorganisms like *E. coli, A. fecalis, S. lutea, P. vulgaris, S. typhosa, P. aeruginosa, M. pyogenes var. aureus, M. pyogenes var. albus* and *S. pyogenes* but failed to inhibit the growth of *A. aerogenes, S. marcescens, B. subtilis* and *H. influenzae*. An aqueous extract was found to be less active. Presence of anthraquinones reported from various plant part (Table 2), and therefore anthraquinones are said to be responsible for antimicrobial activity. Anchel (1949) isolated and identified rhein (Fig. 2) having antibiotic activity.

**Cassia siamea Lam.**

*Cassia siamea* Lam. is the plant which grows widely in South East Asia and is widely used in Thai traditional medicine. The alcoholic extract of flowers has potent antioxidant activity against free radicals, prevent oxidative damage to major biomolecules and afford significant protection against oxidative damage in the liver. *C. siamea* has been reported to contain anthraquinones, alkaloids, flavonoids, chromones, and terpenoids. It is used widely in Thailand and the rest of South East Asia as a food plant and in herbal medicine. The root and bark of *C. siamea*, a tree which is endemic to Central and East Africa, have been used in folklore medicine to treat stomach complaints and as a mild purgative. It is an important source of anthraquinones (Table 2) which are reported from leaves, stem bark, rootbark and heartwood.

Short-term *in vitro* assays for anti-tumor promoters were carried out for several anthraquinones and bianthraquinins, which were isolated from *C. siamea* and derived from cascaroside. Koyama et al. (2001) reported anthraquinone monomers showed higher anti-tumor promoting activity than that of bianthraquinine. It was found that cassiamin B (Fig. 36) might be valuable as an anti-tumor-promoting and chemopreventive agent.

**Cassia sieberiena Linn.**

*Cassia sieberiena* Linn. is a medium-sized tree with compound leaves found in many parts of West Africa. Folkloric evidence supports the use of the species as laxative and purgative in many countries including Nigeria. Presence of various anthraquinone glycosides is responsible for medicinal activity of the plant; however isolation of anthraquinones is not reported from this species. The plant is also found to have antimicrobial activity.

**Cassia singueana Delile**

It is a deciduous shrub or small tree up to 15 m tall, used in northern Nigeria for the treatment of acute malaria attack. Methanol extract of the plant exhibited significant antinoceptive, antipyretic and antiplasmodial activity in all the models. Phytochemical screening of the extract revealed the presence of phenols, saponins, tannins and some traces of anthraquinones. The study also paves way for the possible development of it, as a phytodrug against malaria. Root bark and roots are reported to have anthraquinone (Table 2) and tetrahydroanthracene derivatives with antimicrobial and antispasmodic activities.

**Cassia sophora Linn.**

It is a shrub of up to 2 to 3 m in height with subglabrous stems containing leaves up to 25 cm long. The powdered leaves of *C. sophora* along with hot- and cold-water leaf extracts of this plant were tested in laboratory experiments in the UK and in field trials in Tamale, Northern Ghana, using traditional storage containers, to determine their inhibitory and toxic effects against *Sitophilus oryzae* and *Callosobruchus maculatus* infestation of stored rice and cowpea, respectively. Hot-water extracts might be a more effective technique of applying the plant material on to stored cowpea than using powdered leaves, the currently used application by small-scale farmers. In contrast, experiments with *S. oryzae* on rice showed that *C. sophora* leaf powder (5% w/w) effectively reduced adult emergence in the laboratory, but this could not be confirmed under field conditions. The extracts of root, seed and leaf inhibit germination of *Drechslera oryzae* which can be correlated with presence of various anthraquinones (Table 2) reported from this plant.

**Cassia spectabilis DC.**

It is a fast growing Indian tree, the seeds of which contain about 40% of endosperm are potential source of commercial gum. Anthraquinones (Table 2) are reported mainly from leaves and flower-buds of this plant.

**Cassia tomentosa Linn. f.**

*Cassia tomentosa* Linn f. syn. *Senna multiglandulosa* (Jacq.) Irwin & Barneby, native to
tropical America but widely distributed throughout Africa, Asia, Australasia and Central America is a perennial shrub with yellow flowers which are boiled and eaten. Isolation of sengulone (9-(physcion-7'-yl) -5,10-dihydroxy-2-methoxy-7-methyl-1,4-anthaquinone) (Fig. 37), emodin (Fig. 5), floribundone 1 (Fig. 22), torosanin-9,10'-quinone and anhydrophlegmacin-9',10'-quinone were reported from C. tomentosa.56

*Cassia* *tora* Linn.

It is a small annual legume shrub that grows as a common weed in Asian countries and cultivated as a traditional medicinal herb for multiple therapies including regulation of blood pressure and blood lipid. Sometimes this species is considered as a synonym of *C. obtusifolia*248. *C. obtusifolia* and *C. tora* are distinct in several important phytotoxic characters also. Anthraquinones (obtusin, obtusifolin) (Fig. 33) are confined only to *C. obtusifolia* while chrysobootsuin to *C. tora*.248. Because of naturally occurring acidic soils in southeastern China, this plant species may possess strategies for tolerance to low pH and aluminum toxicity.249,250 *C. tora* is a medicinal plant traditionally used as laxative, for the treatment of leprosy and various skin disorders.251. *C. tora* is effective against free radical mediated diseases.251. The dose-dependent spasmodic effects of the methanolic extract on guinea pig ileum, rabbit jejunum and mice intestinal transit suggested that the use of *C. tora*, traditionally, as a purgative and in the treatment of other ailments is justifiable.252. Ononitol monohydrate isolated from leaves is a potent hepatoprotective agent.253. *C. tora* seed is composed of hull (27%), endosperm (32%) and germ (41%).254. Rheological properties of carbamoyl ethanol *C. tora* gum solutions showed non-Newtonian pseudoplastic behaviour regardless of the % N.255

Seeds have physiological functions as an antiseptic, diuretic, diarrhoeal, antioxidant and antimutagen256. Ethanolic extract of seeds and its ether soluble and water soluble fraction decreased serum level of total cholesterol, triglyceride, LDL-cholesterol on the other hand increase serum HDL-cholesterol.257. Ethyl acetate fraction of methanol extract from *C. tora* exhibited more antioxidant potency and was found to be more effective in protecting LDL against oxidation in a concentration-dependent manner suggesting that *C. tora* especially ethyl acetate-soluble fraction may have a preventive effect against atherosclerosis by inhibiting LDL oxidation.258. Nicoli *et al* (1997) found that medium dark roasted coffee brews had the highest antioxidant properties due to the development of Maillard reaction products.259. Kim *et al* (1994) mentioned that methanol extracts from *C. tora* exhibited strong antioxidant activities on the lipid peroxidation.260.

According to Ayurveda, its leaves and seeds are acrid, laxative, antiperiodic, anthelmintic, ophthalmic, liver tonic, cardiotonic and expectorant. The leaves and seeds are useful in leprosy, ringworm, flatulence, colic, dyspepsia, constipation, cough, bronchitis and cardiac disorders.261. The seeds are reputed in Oriental medicine as vision-improving, antiasthenic, asperient and diuretic agents. *C. tora* have shown to possess various biological and pharmacological activities including antihepatotoxic, radical scavenging, antiallergic, antimutagenic, antifungal and antimicrobial activities.262. Anthraquinone derivatives extracted from the seeds have been used traditionally to improve visual acuity.263. Seeds of *C. tora* being major component used for various pharmacological applications worldwide, is extensively studied for presence of anthraquinones (Table 2) however anthraquinones are also reported to be present in all the parts of *C. tora*.30,248,257,261-277

At 1 g/l, the chloroform fraction of *C. tora* seed extract showed strong fungicidal activities against *Botrytis cinerea*, *Erysiphe graminis*, *Puccinia infestans* and *Rhizoctonia solani*. Emodin (Fig. 5), physcion (Fig. 3) and rhein (Fig. 2) were isolated from the chloroform fraction using chromatographic techniques and showed strong and moderate fungicidal activities against *B. cinerea*, *E. graminis*, *P. infestans* and *R. solani*.264. Furthermore, aloe-emodin (Fig. 4) showed strong and moderate fungicidal activities against *B. cinerea* and *R. solani*, respectively, but did not inhibit the growth of *E. graminis*, *P. infestans*, *P. recondita* and *Pyrularia grisea*.264.

One component found in seeds of *C. tora*, 2-hydroxy-1,6,7,8-tetramethoxy-3-methylanthraquinone, is known as chrysoobutusin and exhibits a variety of potent biological effects such as suppression of mutagenicity of mycotoxins, antioxidant activity and hypolipidemic activity.257,263. Nine anthraquinones, auranto-obutusin, chryso-obtusin, obtusin, chryso-obtusin-2-O-β-D-glucoside, physcion, emodin, chrysophanol, obtusifolin, and obtusifolin-2-O-β-D-
glucoside, isolated from an EtOAc-soluble extract of the seeds of *C. tora*, which are found to contain inhibitory activity on protein glycation and aldose reductase.\textsuperscript{262}

Roasted seeds of the species have a special flavour and colour, and it is popularly used to make a health drink. The commercial products include both unroasted and roasted samples, and the laxative effect was found to be higher in unroasted samples than in the roasted samples.\textsuperscript{265} Zhang *et al* (1996) reported that some components, e.g., chrysophanol, in *C. tora* were decreased after the roasting process.\textsuperscript{266} Yen and Chung (1999) indicated that the antioxidant activity of methanol extracts was stronger than that of *C. occidentalis* and they also identified an antioxidative compound as 1,3,8-trihydroxy-6-methyl-9,10-anthracenediene (emodin) from *C. tora*. However, whether the extracts of *C. tora* possess a prooxidant action towards biological molecules remains unclear.\textsuperscript{266} Antigenotoxic properties and the possible mechanisms of water extracts from *C. tora* (WECT) treated with different degrees of roasting (unroasted and roasted at 150 and 250°C) were evaluated by the Ames salmonella/microsome test and the comet assay. Results indicated that WECT, especially unroasted *C. tora* (WEUCT), markedly suppressed the mutagenicity of 2-amino-6-methylidipyrdo(1,2-a:3′,2′:d)imidazole (Glu-P-1) and 3-amino-1,4-dimethyl-5H-pyrido(4,3-b)indole (Trp-P-1).\textsuperscript{267} WEUCT showed 84% scavenging effect on oxygen free radicals generated in the activation process of mutagen detected by electron paramagnetic resonance system. The individual anthraquinone content in extracts of *C. tora* was measured by HPLC. Three anthraquinones, chrysophanol, emodin and rhein, have been detected under experimental conditions.\textsuperscript{267} The anthraquinone content decreased with increased roasting temperature. Each of these anthraquinones demonstrated significant antigenotoxicity against Trp-P-1 in the comet assay.\textsuperscript{267} The decrease in antigenotoxic potency of roasted *C. tora* was related to the reduction in their anthraquinones.\textsuperscript{267}

Maity and Dinda (2003) isolated and identified that aloes-emin, 1,8-dihydroxy-3-(hydroxymethyl)-anthraquinone from the 90% methanolic extract of the dried leaves. The methanolic extract as well as isolated aloes-emin from leaves was found to contain purgative activity.\textsuperscript{270}

Sui-Ming *et al* (1989) isolated three new anthraquinone glycosides, of which two compounds exhibited a weak protective effect on primary cultured hepatocytes against carbon tetrachloride toxicity.\textsuperscript{271} Chervg *et al* (2008) carried out study of evaluation of the immunostimulatory activities of four anthraquinones, aloe-emin, emodin, chrysophanol and rhein of *C. tora* on human peripheral blood mononuclear cells (PBMC). The results showed that at non-cytotoxic concentrations, the tested anthraquinones were effective in stimulating the proliferation of resting human PBMC and/or secretion of IFN-\(\gamma\). However, at the concentration of 10 \(\mu\)g/ml (35 \(\mu\)M), rhein significantly stimulated proliferation of resting human PBMC (stimulation index (SI)=1.53), but inhibited IFN-\(\gamma\) secretion (74.5% of control). The augmentation of lymphocyte proliferation was correlated to the increase in number of CD4\^T cells, while the elevated secretion of IFN-\(\gamma\) and IL-10 might have been due to the activated CD4\^T cells.\textsuperscript{272} From the extract of seeds alaternin isolated as one of the active radical scavenging principles of DPPH radical, together with the two naphthopyrone glycosides.\textsuperscript{278} Methanol extract of roasted seeds found to have antimutagenic activity against aflatoxin B\(_1\) (AFB\(_1\)). From the methanol extract anthraquinones chrysophanol, aurantiobutin, and chryso-obtusin were isolated as active principle along with alaternin having significant antimutagenic activity.\textsuperscript{275} It is found that alaternin is a potentially effective and versatile antioxidant and can be used to protect biological systems and it functions against various oxidative stresses.\textsuperscript{276}

*Cassia torosa* Cav.

* Cassia torosa* Cav. is reported to contain various anthracene derivatives along with various anthraquinones (Table 2) isolated from different parts of plant.\textsuperscript{277-286} Kitanaka and Takido (1990) reported two new dimeric tetrahydroanthracene derivatives, torosaols I and II from the fresh roots of *C. torosa*. While in further study they reported a new bitetrahydroanthracene derivative, torosaol-III along with phsyscin, 5,7-phsichyanthrone-phsycin, 5,7-biphyisycin, torasnin-9,10-quinone, 5,7-dihydroxy-chromone, naringenin, and chysoeriol from the flowers of *C. torosa*. These compounds exhibited cytotoxic activity against KB cells in the tissue culture.\textsuperscript{284,285}

Conclusion

*Cassia* is a major genus of the Caesalpiniaeae, comprising about 600 species, some of which are used in traditional folk medicines as laxative, purgative,
antimalarial, ulcer healing, anti-diabetic, hepatoprotective, nephroprotective, antitumor and also used in treatment of skin infection and periodical fever throughout tropical and subtropical region. Plants of genus *Cassia* are important source of naturally occurring bioactive compounds anthraquinones. These plants are also reported to have antifungal, antibacterial, antiviral properties along with insecticidal property. Isolation of various anthraquinones from these plants justifies the above mentioned properties. Besides the pharmacological properties anthraquinones are also important as redox mediator in bio-decolorization of dyes and has potential to replace synthesized organic compound used as pesticides, insecticides which associated with carcinogens, toxicants and ecosystem degradation due to its nonbiodegradability and tendency to accumulate in ecosystems. This review highlights the importance of *Cassia* species as an alternative system for biologically active metabolites anthraquinone. The work so far done on *Cassia* species also sets basis for future studies on the effects of anthraquinone containing extracts of the plants which may have important practical implication in grain storage as natural preservative and their potential utilization in development of alternative medicines, novel cancer therapy as well as novel drug to treat viral diseases including polio, AIDS, etc. Antioxidant properties of anthraquinone containing extracts from these plants can be important for protection against number of diseases and reducing oxidation processes in food systems.

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