

CASSIA TORA: ITS CHEMISTRY, MEDICINAL USES AND PHARMACOLOGY

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Summary

Cassia tora Linn. (Caesalpinaceae) is a well known oriental herb or undershrub, found as a rainy season weed throughout India. Traditionally, the whole plant as well as specific parts such as leaves, seeds and roots have been widely used against different diseases. It is a rich source of anthraquinone glycosides. A wide range of chemical compounds have been isolated from this plant. It has variety of biological/pharmacological activities such as hepatoprotective, anti-inflammatory, antigenotoxic, hypolipidemic, spasmogenic and antinociceptive, antiproliferative, immunostimulatory, hypotensive, purgative, antidiabetic, estrogenic and antiestrogenic, antiulcer, antioxidant, antifungal, antishigellosis, anthelmintic, antimutagenic, antibacterial and antiplasmodial activities. The present review summarizes the traditional uses, phytochemical studies and pharmacological profile of *Cassia tora*.

Keywords: *Cassia tora* Linn., traditional uses, phytochemical studies, pharmacological profile.

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Introduction

Since ancient times, mankind all over the world mainly depended upon the plant kingdom to meet their all need of medicines for the treatment of various diseases. Traditional Indian system of medicine, Ayurveda, Sidha and Unani systems are based upon the use of plants. Medicinal plants still play an important role in emerging and developing countries of Asia, both in preventive and curative treatments as these are relatively safe, cost effective and efficacious solutions to primary health care^[1,2].

Cassia tora Linn. (Caesalpinaceae) is a well known oriental herb used in traditional medicine which grows up to 1-2 m in height and is found as a weed throughout India^[3]. It is commonly known as Chakunda in hindi and bengali, Chakramarda in Sanskrit, and Foetid cassia in English^[4]. In Unani, it is known as Sanjisboya^[5]. It is found up to the height of 1400 m in Himachal Pradesh and mainly in wastelands, on roadsides, field borders etc^[6]. It grows abundantly during rainy season, in dry soil throughout the tropical parts^[7]. Flowering/ fruiting of this plant occurs in months of August-October^[6].

Medicinal uses

It constitutes an ayurvedic preparation “Dadrughan-vati” which is used for ringworm, leucoderma, etc^[6]. Chakramardha tailamu, a compound ayurvedic oil of this herb is beneficial in eczema, ringworm and other skin diseases^[3]. In Andhra pradesh, the tribal people had been using the leaves of this plant grounded along with peppers and water into a paste, for the treatment of Jaundice^[8]. The paste of leaves can also be applied to ringworm and eczema. Decoction of leaves and flowers is used internally for bronchitis and asthma^[9]. Plant pacifies vitiated tridosha, dandruff, constipation, cough, hepatitis, fever and haemorrhoids^[10]. The leaves are antiperiodic, alterative, aperient, and given to children having intestinal disorders^[11]. The leaves, roots, and even the whole plant are employed in the treatment of impetigo, ulcers, helmenthiasis and as a purgative^[12]. The pounded leaves are applied as poultice on cuts and wounds like tincture-iodine and for ulcers to hasten suppuration^[3]. Seeds and leaves are also useful in itch, ringworm, and other skin diseases^[13]. Decoction of leaves is a mild laxative in doses of 5 to 15 ml, especially for children having fever while teething. Poultice of the leaves is used locally in gout, sciatica and pains in the joints.

Pods are used in dysentery and in eye diseases. Seeds are also used in eye diseases, liver complaints and earache, leprosy, psoriasis.

Root is considered bitter, tonic, stomachic and is antidote against snake bite^[14,15]. Other uses are in fungal diseases, worm infection, abdominal tumours, bronchitis and asthma^[16]. Other uses of this plant are in abnormal child birth, in bone fracture, cold, epilepsy, night blindness, scabies, scorpion bite, stomachache, vermicide and as substitute for coffee^[17]. Traditional Chinese healers use this herb to treat blindness, xerophthalmia, and conjunctivitis. The seeds are reputed in Chinese medicine as vision improving, antiasthenic, aperient, diuretic and an effective agent in lowering cholesterol and reducing blood pressure^[18].

Young and tender leaves and stems are eaten as a vegetable and in soups. The unripe fruits are also cooked and eaten. The seeds can be introduced as a protein rich food for

livestock. The seeds are used in the preparation of sweets and the powder of the roasted seeds is substituted for coffee. The seeds yield yellow, blue and red coloured dyes used in dyeing and tanning^[3].

Phytochemical Profile

Leaves

Preliminary phytochemical screening of leaf showed the presence of polyphenols which prompted researchers to evaluate its antioxidant and antiproliferative potential^[19]. Presence of Emodin, kaempferol-2-diglucoside is reported in the leaves. Leaves also contain chrysophanol, aloe-emodin, rhein, glucose, 1-stachydrine, amino acids, fatty acids, d-mannitol, β -sitosterol, myricyl alcohol, trigonelline, choline^[3,20]. Ononitol monohydrate, structurally similar to glycoside was isolated from *Cassia tora* Linn. leaves^[21].

Seeds

Seeds contain anthraquinones namely, aurantio-obtusin, chryso-obtusin, obtusin, chryso-obtusin-2-O-beta-D-glucoside, physcion, emodin, chrysophanol, obtusifolin, obtusifolin-2-O-beta-D-glucoside^[22] and anthraquinone glucoside, namely, alaternin 2-O- β -D-glucopyranoside^[23]. Seeds contain Brassinosteroids (Brassinolide, castasterone, typhasterol, teasterone, and 28-norcastasterone), as well as Monoglycerides (monopalmitin and monoolein)^[24].

Phenolic glycosides such as rubrofusarin triglucoside, nor-rubrofusarin gentiobioside, demethylflavasperone gentiobioside, torachryson gentiobioside, torachryson tetraglucoside and torachryson apioglucoside were also isolated^[25].

Seeds contain Rhein, Aloe emodin, Rubrofusarin and its 6- β -gentiobioside, Nor-rubrofusarin, 8-hydroxy-3-methyl anthraquinone-1 β -gentiobioside, Chrysophanic acid & its 9-anthrone, Aurantio-obtusin, 1-desmethyl aurantio-obtusin, 1-desmethylchryso-obtusin, toralactone, torachryson, Sitosterol^[3]. Two new phenolic triglucosides namely, torachryson 8-O-[beta-D-glucopyranosyl(1-->3)-O-beta-D-glucopyranosyl(1-->6)-O-beta-D-glucopyranoside] and toralactone 9-O-[beta-D-glucopyranosyl-(1-->3)-O-beta-D-glucopyranosyl-(1-->6)-O-beta-D-glucopyranoside], along with seven known compounds were isolated from 70% ethanolic extract^[26]. Seeds also contain Rubrofusarin & its triglucoside, Quercetin, 6-O- β -D glucoside, 6-O- β -D-gentiobioside^[20]. From the roasted seeds of *Cassia tora* L., a new naphthopyrone glycoside was isolated and characterized as 10-[\beta-D-glucopyranosyl-(1 \rightarrow 6)-O- β -D-glucopyranosyl]oxy]-5-hydroxy-8-methoxy-2-methyl-4H-naphtho[1,2-b]pyran-4-one(isorubrofusarin gentiobioside). Along with isorubrofusarin gentiobioside, alaternin and adenosin were isolated and identified^[27]. Three naphthopyrone glucosides, cassiaside, rubrofusarin-6-O- β -D-gentiobioside and toralactone-9-O- β -D-gentiobioside isolated from the BuOH-soluble extract of the seeds were using an *in vitro* bioassay based on the inhibition of advanced glycation end products (AGEs) formation. All the isolates were evaluated for the inhibitory activity on AGEs formation *in vitro*^[28]. From the seeds of *Cassia tora*, questin, 2-hydroxyemodin 1-methylether were isolated from for the first time^[29]. From the seeds of *Cassia tora*, a new naphthalene glycoside was isolated and

characterized as 2-acetyl-3-O- β -D-apiofuranosyloxy-8-O- β -D-glucopyranosyloxy-1,6-dimethoxynaphthalene (Cassiatoraside)^[30] as shown in table 1.

The seeds yield a gum (7.65%) which is the most efficient suspending agent for calomel, kaolin and talc^[31]. Extraction of the dried and crushed seeds with petroleum ether (b.p. 60-80°C) in a specially modified soxhlet apparatus gave 5.0% brownish yellow oil. Subsequently, Chrysophanic acid was also isolated from this oil^[31]. Mucilage (25.8%) was isolated from the seeds by extraction with hot water. Mucilage Sample was then hydrolysed to determine the sugar component. Two hexose sugars, mannose and galactose were found. In this way the mucilage sample was considered as galactomannan type of polysaccharide^[32].

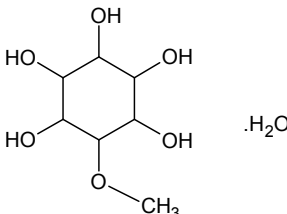
Stem bark

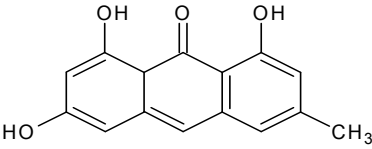
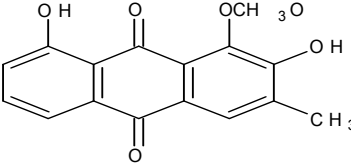
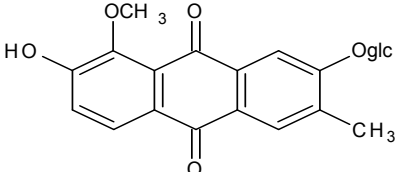
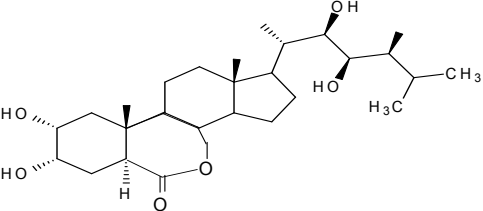
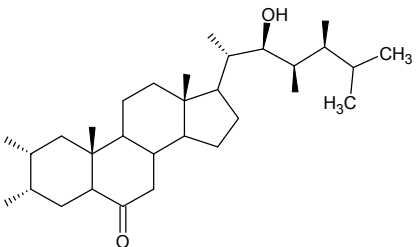
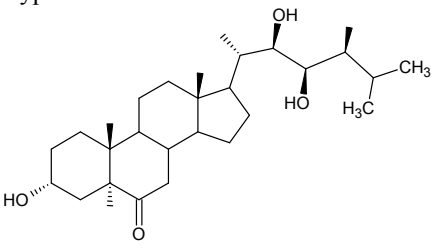
The isolation of a rare anthraquinone, 1-hydroxy-5-methoxy-2-methyl anthraquinone and its glycoside, 5-methoxy-2-methyl anthraquinone-1-O- α -L-rhamnoside along with chrysophanol, emodin and β -sitosterol from the stem of *Cassia tora* Linn. is reported^[33]. The stem also contain d-mannitol, myricyl alcohol, β -sitosterol, glucose, tigonelline, 1-stachydnine and choline. The stembark yields ethyl arachidate and behenic acids, marginic and palmitic acids, euphol, aurapterol, basseol, rhein, 3,5,8,3'4'5'-hexahydroxy flavones^[3].

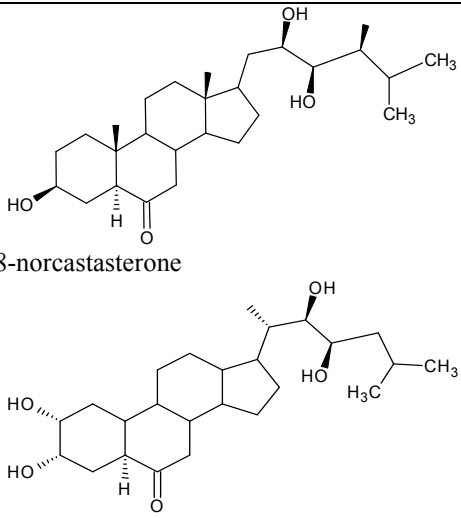
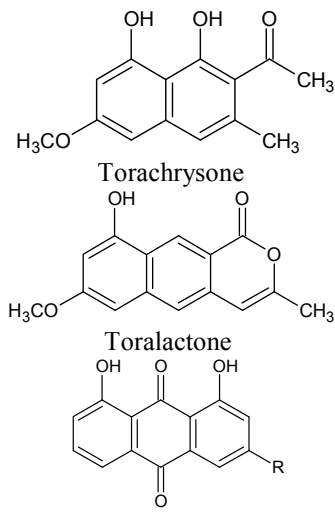
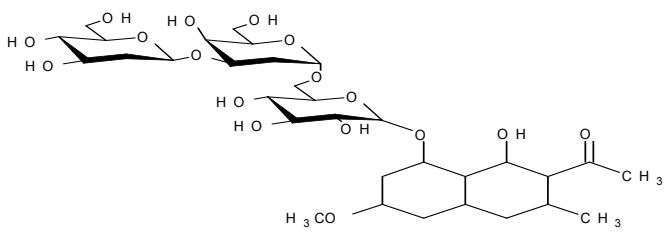
Roots

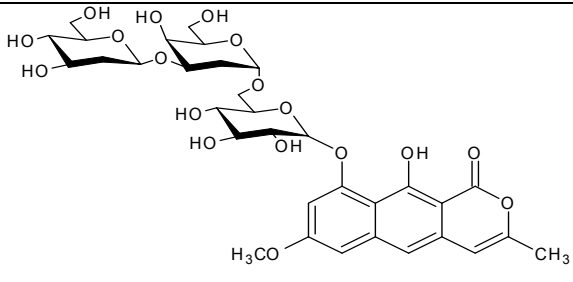
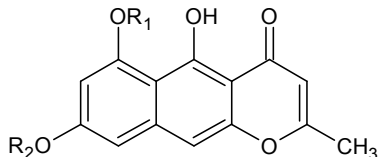
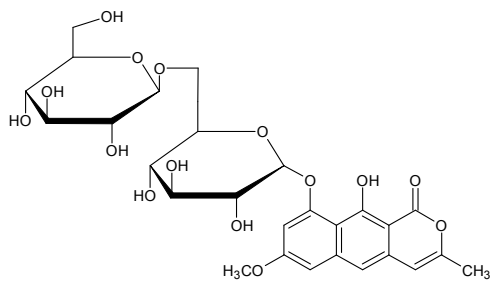
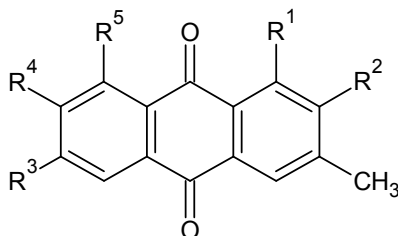
Roots contain Choline, 1,3,5-trihydroxy-6,7-dimethoxy-2-methylanthraquinone^[3], Myricyl alcohol, chrysophanic acid & its 9-anthrone, Naphtho- α -pyrone, Physcion, Rubrofusarin & its 6 β gentiobioside, toralactone, Leucopelargonidin-3-O- α -L-rhamnopyranoside, β -sitosterol^[20].

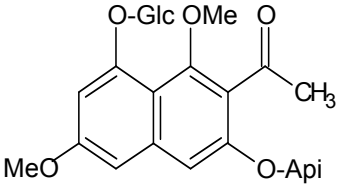
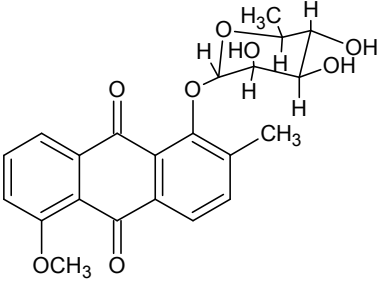
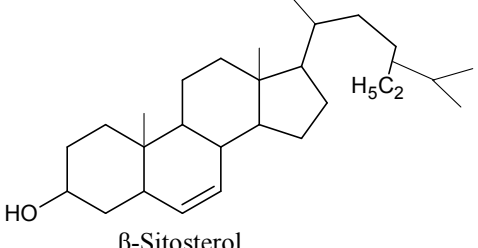
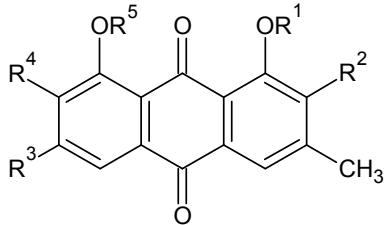
Table. 1 Some Important Chemical Constituents Isolated from the herb *Cassia tora*

Structure	Extract	Activities
<p>I</p>  <p>6-methoxycyclohexane-1,2,3,4,5-pentol hydrate (Ononitol Monohydrate)</p>	Hexane: Ethyl Acetate fraction	Hepatoprotective Activity (21)

<p>II</p>  <p>Emodin</p>  <p>Obtusifolin</p>  <p>Chryso-obtusin-2-O-β-D-glucoside</p>	<p>Ethyl Acetate fraction</p> <p>Ethyl Acetate fraction</p> <p>Ethyl Acetate fraction</p>	<p>Inhibition of AGE (22)</p> <p>Inhibition of AGE (22)</p> <p>Inhibition of RLAR (22)</p>
<p>III Brassinosteroids</p> <p>1. Brassinolide</p>  <p>2. Castasterone</p>  <p>3. Typhasterol</p>  <p>4. Teasterone</p>		<p>Bioactive Compounds in Rice Lamina Bioassay (24)</p>

 <p>5. 28-norcastasterone</p>		
<p>IV Phenolic Constituents</p>  <p>Torachryson</p> <p>Toralactone</p> <p>Aloe-emodin (R= CH₂OH)</p> <p>Rhein (R= COOH)</p>		Antibacterial Activity (25)
<p>V Phenolic Triglycosides</p> <p>1. Torachryson 8-O-[β-D-glucopyranosyl(1→3)-O-β-D-glucopyranosyl (1→6)-O-β-D-glucopyranoside]</p>  <p>2. Toralactone 9-O-[β-D-glucopyranosyl-(1→3)-O-β-D-glucopyranosyl-(1→6)-O-β-D-glucopyranoside]</p>		Estrogenic & Antiestrogenic Activities (26)

		
<p>VI</p>  <p>Compound</p> <p>1. Cassiaside</p> <p>2. Rubrofusarin-6-O-β-D-gentiobioside</p> <p>R₁</p> <p>glucosyl</p> <p>gentiobiosyl</p> <p>R₂</p> <p>H</p> <p>CH₃</p>  <p>Toralactone-9-O-β-D-gentiobioside</p>	<p>Butanol soluble fraction of methanol extract</p>	<p>Inhibitory activity on Advanced glycation end (AGE) product formation (28)</p>
<p>VII</p>  <p>Compound</p> <p>Questin</p> <p>2-hydroxy emodin 1-methyl ether</p> <p>Glucoaurantio-obtusin</p> <p>R¹ R² R³ R⁴ R⁵</p> <p>OH H OH H OMe</p> <p>OMe OH OH H OH</p> <p>OMe OH O-Glu OMe OH</p>	<p>n-hexane-EtOAc fraction (5:1)</p>	<p>Marked ACE inhibitory activity demonstrated by Glucoaurantio-obtusin (29)</p>

<p>VIII</p>  <p>Cassiatoraside</p>	Butanol fraction	(30)																								
<p>IX</p>  <p>1-hydroxy-5-methoxy-2-methyl anthraquinone</p>  <p>β-Sitosterol</p>	<p>Benzene: EtOAc (7:3)</p> <p>Petroleum ether- Benzene (8:2 v/v) eluate of Pet. Ether extract</p>	(33)																								
<p>X</p>  <table border="1" data-bbox="143 1422 774 1579"> <thead> <tr> <th>Compound</th> <th>R¹</th> <th>R²</th> <th>R³</th> <th>R⁴</th> <th>R⁵</th> </tr> </thead> <tbody> <tr> <td>Chrysophanol</td> <td>H</td> <td>H</td> <td>H</td> <td>H</td> <td>H</td> </tr> <tr> <td>Chrysoobtusin</td> <td>CH₃</td> <td>OH</td> <td>OCH₃</td> <td>OCH₃</td> <td>CH₃</td> </tr> <tr> <td>Aurantioobtusin</td> <td>CH₃</td> <td>OH</td> <td>OH</td> <td>OCH₃</td> <td>H</td> </tr> </tbody> </table>	Compound	R ¹	R ²	R ³	R ⁴	R ⁵	Chrysophanol	H	H	H	H	H	Chrysoobtusin	CH ₃	OH	OCH ₃	OCH ₃	CH ₃	Aurantioobtusin	CH ₃	OH	OH	OCH ₃	H	CH ₂ Cl ₂ fraction (Methylene chloride)	Antimutagenic (61)
Compound	R ¹	R ²	R ³	R ⁴	R ⁵																					
Chrysophanol	H	H	H	H	H																					
Chrysoobtusin	CH ₃	OH	OCH ₃	OCH ₃	CH ₃																					
Aurantioobtusin	CH ₃	OH	OH	OCH ₃	H																					

Pharmacological Profile

All over the world scientific research is getting momentum to evaluate the pharmacological activities and medicinal properties of *Cassia tora* L. On the basis of various experimental researches, the following pharmacological activities or medicinal properties of *Cassia tora* L. have been reported.

Hepatoprotective Activity

Methanolic extract of leaves at a dose of 400 mg/kg showed significant hepatoprotective effect by lowering the serum levels of transaminase (SGOT and SGPT), bilirubin and alkaline phosphatase (ALP)^[34].

Hydroalcoholic extracts of *Cassia tora* whole plant showed significant decrease in the levels of serum markers, indicating the protection of hepatic cells and significant dose-dependent protection against paracetamol induced hepatocellular injury^[35].

Ononitol monohydrate isolated from leaves decreased levels of serum transaminase, lipid peroxidation and TNF- α but increased the levels of antioxidants and hepatic glutathione enzyme activities. Compared with reference drug silymarin, ononitol monohydrate possessed high hepatoprotective activity^[21].

Anti-inflammatory activity

Methanolic extract of the leaves was investigated against carrageenin, histamine, serotonin and dextran induced rat hind paw oedema. It exhibited significant anti-inflammatory activity against all these agents. The extract (400 mg/kg) showed maximum inhibition of oedema of 40.33%, 31.37%, 53.57% and 29.15% at the end of 3 hr with carrageenin, dextran, histamine and serotonin induced rat paw oedema, respectively. Using a chronic test, the granuloma pouch in rats, the extract exhibited a 48.13% reduction in granuloma weight^[36].

Antigenotoxic Properties

Antigenotoxic properties and the possible mechanisms of water extracts from *Cassia tora* L. (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-methylpyrido(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). In the Comet assay performed on human lymphocytes, WECT exhibited significant protective effect on Trp-P-1-mediated DNA damage followed the order of unroasted (55%) > roasted at 150°C (42%) > roasted at 250°C (29%). Pre-treatment of the lymphocytes with WEUCT resulted in 30% repression of DNA damage^[37].

In another study, Cytological effects of *Cassia tora* (*C.tora*) seed decoction were evaluated in *Allium cepa* (*A.cepa*) root tip cells. Bulbs were grown in pure tap water (controls, Gr. I) and also in six concentrations (0.15 mg/ml, 0.31 mg/ml, 0.62 mg/ml, 1.25 mg/ml, 2.5 mg/ml and 5 mg/ml) of *C.tora* seed decoction in tap water (experimental, Grs. II). Parameters of study were 'mean root length' and morphology i.e. colour and shape of root tips at 72 hr of cultivation and 'mitotic Index', chromosomal aberrations and abnormal mitosis at 48 hr of cultivation. Physico-chemical characterization of decoction was also made. Results suggested that water soluble constituents of *C.tora* seeds could only lower mitosis but not caused any adverse genotoxic effects in mitotically dividing *A.cepa* root cells under laboratory condition^[38].

In another study, the effects of water extracts from *Cassia tora* L. (WECT) treated with different degrees of roasting on benzo[a]pyrene (B[a]P)-induced DNA damage in human hepatoma cell line HepG2 were investigated via the comet assay without exogenous activation mixtures, such as S9 mix. WECT alone at concentrations of 0.1-2 mg/ml, showed neither cytotoxic nor genotoxic effect toward HepG2 cells. B[a]P induced DNA damage in HepG2 cells could be reduced by WECT in a dose dependent manner ($P < 0.05$). At a concentration of 1 mg/ml, the inhibitory effects of WECT on DNA damage were in the order unroasted (72%) > roasted at 150°C (60%) > roasted at 250°C (23%). Ethoxycorufin-O-dealkylase activity of HepG2 cells was effectively inhibited by WECT, and a similar trend of inhibition was observed in the order unroasted (64%) > roasted at 150°C (42%) > roasted at 250°C (18%). The activity of NADPH cytochrome P-450 reductase was also decreased by unroasted and 150°C roasted samples (50% and 38%, respectively). In addition, the contents of anthraquinones (AQs) in WECT, including chrysophanol, emodin and rhein were decreased with increasing roasting temperature. Each of these anthraquinones also demonstrated significant antigenotoxic activity in the comet assay. The inhibitory effects of chrysophanol, emodin, and rhein on B[a]P-mediated DNA damage in HepG2 cells were 78, 86 and 71%, respectively, at 100 μ M. These findings suggested that the decreased antigenotoxicity of the roasted samples might be due to a reduction in their AQs content^[39].

Hypolipidemic Activity

Ethanollic extract of seeds and its ether soluble and water soluble fraction decreased serum level of total cholesterol by 42.07, 40.77 and 71.25% and increased the serum HDL-cholesterol level by 6.72, 17.20 and 19.18%, respectively. Ethanollic extract, ether fraction and water fraction decreased triglyceride level by 26.84, 35.74 and 38.46%, respectively. The reduction in LDL-cholesterol level by ethanollic extract, ether soluble fraction and water soluble fraction were 69.25, 72.06, and 76.12%, respectively^[40].

In another study, soluble fibres isolated from the seeds were investigated for effect on lipid metabolism. The serum concentration of total cholesterol in rats fed Soluble fibre was 27% lower ($p < 0.05$) compared to that of the control group, liver total cholesterol and triglyceride levels were also reduced significantly ($p < 0.05$) but the serum high-density lipoprotein cholesterol level was increased in the soluble fibre group^[41].

Spasmogenic and Antinociceptive activity

The leaves of *Cassia tora* Linn. (Family: Caesalpinaceae) were soxhlet extracted with methanol. The spasmogenic effects of the extract were evaluated on guinea pig ileum, rabbit jejunum and mice intestinal transit. Antinociceptive activity of the extract was also evaluated in the mice. The extract contracted smooth muscles of guinea pig ileum and rabbit jejunum in a concentration dependent manner. The extract increased intestinal transit in mice dose dependently and reduced the number of acetic acid induced abdominal constrictions in mice and the effect was comparable to that of aspirin. The extract also significantly reduced the nociceptive response of mice to increased force. The effects were dose dependent^[42].

Nitric Oxide Scavenging Activity

The methanolic leaf extract of *Cassia tora* was evaluated for its nitric oxide scavenging activity and reducing power assays using Rutin and BHT as standards. The extract was studied for its lipid peroxidation inhibition assay using rat liver and brain. In all assays, a correlation existed between concentration of extract and percentage inhibition of free radical, reducing power and inhibition of lipid peroxidation^[19].

Antiproliferative Activity

The antiproliferative activity of *Cassia tora* methanolic leaf extract with Cisplatin, anticancer drug was studied using human cervical cells (HeLa). Proliferation of HeLa was measured by MTT assay, cell DNA content by modified diphenylamine method and apoptosis by Caspase 3 activity. The plant extract induced a marked concentration dependent inhibition on proliferation, reduced DNA content and apoptosis in HeLa^[19].

Immunostimulatory Activity

Immunostimulatory activities of four anthraquinones of *Cassia tora* (aloe emodin, emodin, chrysophanol, and rhein) was evaluated on human peripheral blood mononuclear cells (PBMC). Studies were conducted on lymphocyte proliferation by BrdU immunoassay, secretion of interferon-gamma (IFN- γ) and interleukin 10 (IL-10) by an ELISA assay and elucidation of responding immune cells by flow cytometry. 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- γ . However, at the concentration of 10 μ g/ml (35 μ M), rhein significantly stimulated proliferation of resting human PBMC (stimulation index (SI) = 1.53), but inhibited IFN- γ 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- γ And IL-10 might have been due to the activated CD4⁺ T cells^[43].

Ethanol extract and solvent fractions, n-hexane, chloroform, ethylacetate, n-butanol and aqueous layer of *Cassia tora* L. seed were tested for immunostimulating activity *in vitro*. The ethylacetate-soluble fraction caused significant inhibition on the production of nitric oxide by murine macrophages (RAW 264.7), and mouse splenocytes were also stimulated at the concentration of 10 μ g/ml^[44].

Hypotensive activity

The bioactivity of seeds from raw and roasted *Cassia tora* was screened via angiotensin converting enzyme (ACE) inhibitory assays. It was found that both of the MeOH extracts from the raw and roasted *Cassia tora* exhibited significant inhibitory properties against ACE, demonstrated more than 50% inhibition at a concentration of 163.93 μ g/ml. Glucourantioobtusin was isolated which demonstrated marked inhibitory activity against ACE with IC₅₀ value of 30.24 \pm 0.20 μ M^[29]. Medial portion of the medullary reticular formation has been identified to be directly involved in the hypotensive effect of extracts from the seeds from *Cassia tora*^[45].

Metabolic Studies

Aloe-emodin (1,8-dihydroxy 3-Hydroxy Methyl Anthraquinone) was isolated from the leaves of this plant and its metabolic pattern was studied. The results showed that about 15.4% of the administered aloe-emodin was excreted and the rest was probably bound or metabolized in the system^[46].

Purgative Activity

The purgative action of the crude extract (100 and 200 mg/kg) and material isolated from *Cassia tora* leaves were studied by two methods such as counting of characteristic diarrhoeal dropping method and gastrointestinal motility test by administration of charcoal meal in rats. Both the materials possess good purgative action^[47].

Antidiabetic Study

The effects *Cassia tora* L. seed butanol fraction (CATO) were studied on postprandial glucose control and insulin secretion from the pancreas of the normal and diabetic rats. Diabetes was induced by an i.p. injection of streptozotocin (55 mg/kg BW) into the male Sprague-Dawley rats. The postprandial glucose control was monitored during a 240 min-period using a maltose loading. In normal rats, rats fed CATO (20 mg/100 g BW/d) showed lower postprandial glucose levels in all the levels from 30 min up to 180 min than those in the control rats without CATO ($p < 0.05$). In diabetic rats, those levels in the CATO group seemed to be lower during the 30~180 min, but only glucose level at 30 min showed significant difference compared to that in the control group. Moreover, CATO delayed the peak time of the glucose rise in both normal and diabetic rats in the glucose curves. On the other hand, when CATO was administered orally to the diabetic rats for 5 days, 12 hr fasting serum glucose level was decreased in the diabetic rats ($p < 0.05$). Degree of a decrease in 12 hr fasting serum insulin levels was significantly less in the diabetic CATO rats as compared to diabetic control rats. On the last day of feeding, β cells of the pancreas were stimulated by 200 mg/dL glucose through a 40 min-pancreas perfusion. Amounts of the insulin secreted from the pancreas during the first phase (11~20 min) and the second phase (21~40 min) in the CATO fed diabetic rats were significantly greater than those in the diabetic control group ($p < 0.05$). These findings indicated that constituents of *Cassia tora* L. seeds have beneficial effect on postprandial blood glucose control which may be partially mediated by stimulated insulin secretion from the pancreas of the diabetic rat^[48].

In another study, *Cassia tora* fiber supplement consisting of 2 g of soluble fiber extracted from *Cassia tora* L., decreased serum total cholesterol and the levels of serum triglycerides and low-density lipoprotein-cholesterol^[49].

Estrogenic and Antiestrogenic Activity

The estrogenic activity of the fractions and the isolated compounds obtained from 70% ethanolic extract were investigated using the estrogen-dependent proliferation of MCF-7 cells. Furthermore, a naringinase pre-treatment of the 70% alcoholic extract of *Cassia tora* seeds

resulted in a significant increase in its estrogenic activity. From the naringinase pre-treated extract six compounds were isolated, among which 6-hydroxymusizin and aurantio-obtusin showed the most potent estrogenic activity, while torachryson, rubrofusarin and toralactone showed a significant anti-estrogenic activity. Finally, the structure requirements responsible for the estrogenic activity of the isolated compounds were studied by investigating the activity of several synthetic compounds and chemically modifying the isolated compounds. The basic nucleus 1,3,8-trihydroxynaphthalene (T(3)HN) was found to play a principal role in the binding affinity of these compounds to ER^[26].

Antiulcer Activity

Antiulcer effect of methanolic extract of *Cassia tora* seed extract was evaluated using pylorus ligation and indomethacin induced ulcers in wistar albino rats. Experimental animals were divided into five groups namely control, standard, normal and two extract treated groups. Various biochemical parameters such as gastric volume, free and total acidity were estimated. A significant reduction of ulcer index as well as gastric acid output in extract treated animals was observed with respect to control animals. The extract exhibited 75% protection in pylorus ligation model and 70.31% protection in indomethacin induced ulcers at concentration of 200 µg/ml which was comparable to standard drug, ranitidine^[50].

In another study, the antiulcer activity of hydroalcoholic extract of *Cassia tora* leaves was evaluated in albino rats using ethanol induced gastric ulcer model. The parameters taken to assess the antiulcer activity were ulcer score, ulcer index, gastric juice volume, pH, free and total acidity. The extract of leaves of *Cassia tora* showed dose dependent antiulcer activity with maximum activity at 500 mg/kg body weight. The effect at this dose was found to be comparable with that of reference standard, Omeprazole 20 mg/kg^[51].

Antioxidant Activity

The antioxidant properties of water extracts from *Cassia tora* L. (WECT) prepared under different degrees of roasting were investigated. The water extracts of unroasted *Cassia tora* L. (WEUCT) showed 94% inhibition of peroxidation of linoleic acid at a dose of 0.2 mg/ml which was higher than that of α -tocopherol (82%). Water extracts prepared from *Cassia tora* L. roasted at 175° C for 5 min and at 200° C for 5 min exhibited 83% and 82%, respectively, inhibition of linoleic acid peroxidation^[52].

In another study, the methanol extract from juemingzi (*Cassia tora* L.) was fractionated by liquid-liquid partition using ethyl acetate, n-butanol, and water respectively. Among these fractions, ethyl acetate fraction exhibited more antioxidant potency than other fractions and this fraction was found to be more effective in protecting LDL against oxidation in a concentration-dependent manner. The data suggest that juemingzi, especially ethyl acetate soluble fraction may have a preventive effect against atherosclerosis by inhibiting LDL oxidation^[53].

In another study, the antioxidant activity of prepared skin herbal cosmetic cream and lotions comprising ethanolic extracts of *C.asiatica*, *G.glabra*, *E.officinale*, *P.granatum*, *A.catechu*, *C.zeylanicum*, *P.cordifolia*, *C.tora*, *A.vera* in various concentrations was evaluated and compared. The relative antioxidant activity was compared with standard antioxidant

activity of L-ascorbic acid. Results indicated that the cream and lotion formulations comprising extracts possess antioxidant activity as compared to standard L-ascorbic acid^[54].

In another study, antioxidant activity of aqueous and alcoholic extract *Cassia tora* Linn leaves. Results showed that aqueous extract possessed stronger antioxidant and antiradical activities than ethanolic extract in nitric oxide, DPPH (1, 1-diphenyl-1, 2-picryl hydrazyl), ABTS (2, 2-Azino-bis 3-ethyl benothiazoline-6-sulfonic acid diammonium salt) radical scavenging assay with IC values 769.23±2.63, 1059.78±2.23, 490.08±2.45µg/ml in aqueous extract and 1000.51±2.21µg/ml, 1700.03±1.18 and 943.23±1.38µg/ml in ethanolic extract, respectively^[55].

Antifungal Activity

The antifungal activity of dealcoholized extract of leaves of *Cassia tora* Linn. on five different fungal organisms was determined. Crude leaf extract significantly inhibited the growth of *C.albicans*, *A.niger*, *S.cerevisiae* and *T.mentagophytes* when tested by turbidity and spore germination methods in a concentration dependent fashion^[56].

In another study, ethanolic extracts of *Cassia tora* seeds and leaves showed positive results for *Candida albicans* and *Microsporum canis*, respectively^[57].

The fungicidal activities of *Cassia tora* extracts and their active principles were determined against *Botrytis cineria*, *Erysiphe graminis*, *Phytophthora infestans*, *Puccinia recondita*, *Pyricularia grisea*, and *Rhizoctonia solani* using a whole plant method *in vivo*. The responses varied with the plant pathogen tested. At 1 g/L, the chloroform fraction of *C. tora* showed a strong fungicidal activity against *B. cinerea*, *E. graminis*, *P. infestans*, and *R. solani*. Emodin, physcion, and rhein 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*. Furthermore, aloe-emodin showed strong and moderate fungicidal activities against *B. cinerea* and *R. solani*, respectively^[58].

Antishigellosis Activity

The ethylacetate fraction of the crude extract showed maximum activity with the zone of inhibition ranging between 23-25 mm at the concentration of 200 µg disc⁻¹. The minimum inhibitory concentration (MIC) of ethylacetate, chloroform and ethanol extracts was found between 32-64 µg ml⁻¹ whereas the methanol and petroleum fractions showed MIC values between 128-512 µg ml⁻¹^[59].

Anthelmintic Activity

Alcohol and aqueous extract of seeds were investigated for their anthelmintic activity against *Pheretima posthuma* and *Ascardia galli*. Three concentrations (25, 50 and 100 mg/ml) of each extracts were studied in activity, which involved the determination of time of paralysis and time of death of the worm. Both the extracts exhibited significant anthelmintic activity at highest concentration of 100 mg/ml^[60].

Antimutagenic Activity

Antimutagenic activity of a methanol extract of seeds was demonstrated against aflatoxin B₁ with the *Salmonella typhimurium* assay. The numbers of revertants per plate decreased significantly when this extract was added to the assay system using *Salmonella typhimurium* TA100 and/or TA98. The methanol extract was then sequentially partitioned with CH₂Cl₂, n-butanol and H₂O. The CH₂Cl₂ and n-butanol fractions possessed antimutagenic activity but the H₂O fraction was inactive. Column chromatography using silica gel yielded pure chrysophanol, chrysoobtusin and aurantioobtusin from CH₂Cl₂ fraction and cassiaside and rubro-fusarin gentiobioside from the n-BuOH fraction. Each of these compounds demonstrated significant antimutagenic activity^[61].

Antibacterial Activity

Dealcoholized extract of seeds of *Cassia tora* inhibited the growth of *Micrococcus pyogenes* var. albus, *Micrococcus citreus*, *Cornebacterium diphtheria*, *Bacillus megatherium*, *Salmonella typhosa*, *Salmonella paratyphi*, *Salmonella schottmuelleri* and *Escherichia coli*^[62].

The effects of the phenolic glycosides, their aglycones and several other compounds structurally related to them were examined on *Escherichia coli* K12, *Pseudomonas aeruginosa* PAO1 and some strains of *Staphylococcus aureus*. Among them torachryson, toralactone, aloe-emodin, rhein and emodin isolated from seeds showed noticeable antibacterial effects on four strains of methicillin-resistant *Staphylococcus aureus* with a minimum inhibitory concentration of 2-64 µg/ml^[25].

Another study reports the antibacterial activity of the aqueous, petroleum ether, methanolic and ethanolic extract of *Cassia tora* L. which were subjected to antibacterial evaluation against both gram positive and gram negative organisms by cup plate technique. Aqueous extracts of seeds of *Cassia tora* exhibited better antibacterial activity as compared to its petroleum ether, methanolic and ethanolic extracts. Among the organisms tested *S. aureus* was more susceptible to the aqueous extract of this herb^[63].

In a study by Das G *et al*, the chloroform, methanol and aqueous extract of leaves of *Cassia tora* L. showed antibacterial activity (0-5000 µg/ml) against 38, 58 and 29 bacterial strains respectively out of 120 various bacterial strains and also methanol extracts showed antifungal activity (0-64mg/ml) against 3 out of 4 strains. Five strains of *Shigella dysenteriae*, four strains of *Staphylococcus aureus*, and three strains of *Escherichia coli*, have shown sensitivity against *in vitro* treatment of the methanol extracts up to 2000 µg/ml concentration. The minimum inhibitory concentration (MIC) values ranges from 2-64 mg/ml for dermatophytes. Minimal Bactericidal Concentration (MBC) value lies in the range of 2000-2500 µg/ml against *Escherichia coli* ATCC25938 and *Shigella dysenteriae*^[64].

In another study, Ethanolic and Aqueous extracts from the leaves of *Cassia tora* were investigated for their antibacterial activity. Their concentrations 0.15mg, 0.31mg ethanolic and aqueous extracts respectively were studied in activity, which involved the determination of inhibition zone in mm. Both the extracts exhibited significant antibacterial activity^[65].

Antiplasmodial Activity

Antiplasmodial activity was evaluated *in vitro* against *Plasmodium falciparum* 3D7 (chloroquine sensitive) and Dd2 (chloroquine resistant and pyrimethamine sensitive). Plant extracts from *Cassia tora* possessed IC₅₀ values less than 5 µg/ml on both tested strains^[66].

Conclusion

In the present review we have made an attempt to provide the traditional uses, phytochemical and pharmacological profile of *Cassia tora*. The literature survey revealed that *Cassia tora* contain anthraquinone glycosides, phenolic compounds, steroids.

Pharmacological activities reported are hepatoprotective, anti-inflammatory, antigenotoxic, hypolipidemic, spasmogenic and antinociceptive, antiproliferative, immunostimulatory, hypotensive, purgative, antidiabetic, estrogenic and antiestrogenic, antiulcer, antioxidant, antifungal, antishigellosis, anthelmintic, antimutagenic, antibacterial and antiplasmodial.

There are many other traditional uses of *Cassia tora* in ayurveda which serves as basis for further studies. This review will definitely help the researchers to explore its different properties.

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