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(RESEARCH ARTICLE)

A review of *Cassia fistula L*inn potential uses in medicine and health management

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Abstract

Medicinal plants harbor unexplored reservoirs of bioactive molecules with significant therapeutic potential. The present study investigates *Cassia fistula* L., a medium-sized deciduous tree known as "the golden shower." In Ayurvedic Medicine, it is also called a "disease killer" and has historically been employed to treat congestion and upper respiratory tract infections. It derives its name from its attractive yellow flowers and long rod-shaped seeds. Phytochemical analysis revealed a rich nutritional profile comprising fats (12%), free amino acids (1.42%), protein (12%), and carbohydrates (11.75%). The species contains diverse bioactive compounds, including glycosides, tannins, flavonoids, anthraquinone, fistulin, fistulic acids, kaempferol, bianthroquonones, β-sitosterol, hexacosanol, and lupeol. Various plant parts demonstrated distinct therapeutic properties. Leaves and bark exhibited dermatological efficacy; roots showed diuretic potential and treated tubercular glands, heart conditions, and ulcers. Fruit pulp, rich in iron and manganese, displayed mild laxative properties. Modern pharmacological studies have validated multiple therapeutic properties such as hepatoprotective, anti-cancer, anti-pyretic, anti-inflammatory, anti-microbial, anti-fertility, anti-tussive, anti-epileptic, anti-ulcer, and anti-oxidant potential. *Cassia fistula* is a medicinally valuable plant with a rich history of traditional applications, supported by modern pharmacological data. The plant's diverse bioactive compounds and documented therapeutic potential make it a promising candidate for the development of novel plant-based drug. Although existing studies confirm its therapeutic potential, additional standardization and clinical trials are necessary for the advancement of modern pharmaceutical applications. This comprehensive review synthesizes knowledge of *Cassia fistula's* therapeutic potential and provides a foundation for future pharmaceutical research.

Keywords: Bioactive compounds; *Cassia fistula*; Pharmacological activities; Phytochemistry; Traditional medicine; Toxicology

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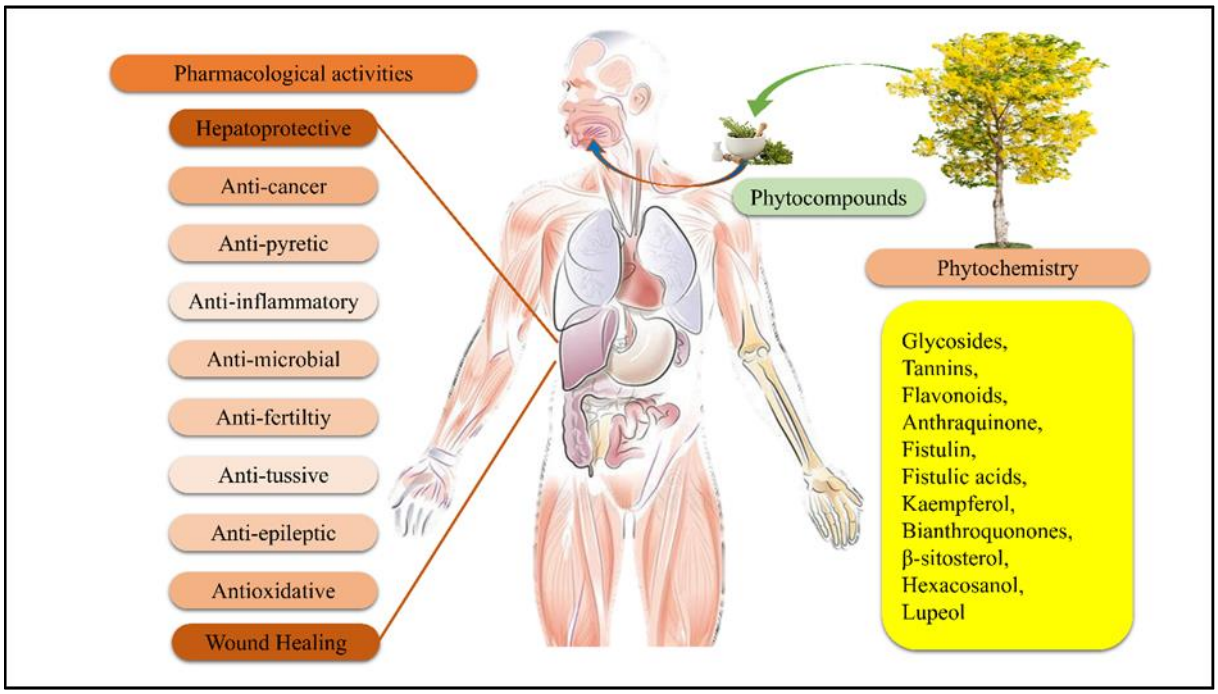
Graphical abstract



1. Introduction

Various ancient medicinal systems, including Chinese, Ayurvedic, Siddha, Unani, etc., use the plant as a source of therapeutic potential. Due to their low toxicity and affordability, medicinal plants have recently experienced a boom in demand [1]. These systems recognized the therapeutic values of herbal products and have been employed effectively in health treatment for centuries [2]. *Cassia* is a member of the *Fabaceae* family and the subfamily *Caesalpinioideae* of the *Fabales* order [3]. "*Cassia*" is derived from the traditional term for a Chinese aromatic bark (*Cinnamomum Cassia*) that is related to cinnamon [4]. The genus *Cassia* is widely spread throughout the world and has been utilized as a prospective medicinal plant since ancient times [5]. Taxonomically, the genus comprises three distinct subgenera: *Cassia L.*, *Senna Mill.*, and *Chamaecrista Moench,* with recent molecular analyses, particularly DNA markers, facilitating more precise taxonomic classification [6]. Approximately 5000 species of flowering plants belong to the broad tropical genus *Cassia* and are found all over Africa, Asia, and North and South America [7]. Approximately 580 species are recognized for their physiologically active macromolecules, and 20 Indian species are used to treat chronic disorders. *C. fistula* Linn. is native to India and widely grown for its showy yellow blooms [8]. *C. fistula* Linn., also known as Amaltas, Gurmala, Pudding Pipe Tree, Golden Shower, Indian Laburnum, and Purging *Cassia*. According to the *Ayurvedic* classification of treatments, this plant, referred to as Aragvadha, means a "disease killer". Chronic disorders such as syphilis, amenorrhea, leprosy, and cardiac diseases are treated by using bark decoction of *C. fistula* in the Unani. Due to its abundant and appealing therapeutic characteristics, it is listed in the British Pharmacopoeia [9].

1.1. Geographical distribution

Cassia species are perennial shrubs native to tropical regions. They thrive as weeds in wastelands during the monsoon season. It grows in low coastal areas, waste areas, and river edges. It is found in moist areas such as uninhabited areas at elevations ranging from 1000 to 1400 meters. This golden shower tree is widely distributed in India, Brazil, South and East Africa, Pakistan, Bangladesh, the West Indies, Mexico, and western China [10]. Across India, *Cassia* is cultivated for ornamental purposes in tropical areas because of its yellow blooms [11,12]. It mounts up to 1300m in the outer Himalayas [13]. It is also found in Maharashtra's Deccan and Konkan regions [8].

1.2. Botanical description

C. fistula is a moderately sized (8-15m) deciduous tree (Figure 1A). Its leaves are compound, alternating, pinnate, and deciduous with 3-8 leaflet pairs [14]. The leaflet is 5-12cm, with different types of stipules with petiolar glands [6] (Figure 1B). The leaves fall off around March, and a thick pubescence can be found beneath the midribs [15]. It has a straight trunk with long and dense branches. The bark gets more rigid as it ages. Smooth young bark turns rough and dark brown when fully grown. The outer bark's thick, curved, flat fragments can be soft or rough with warty spots. Its

inner green-gray surface turns red with parallel striations, which can be laminated or fractured. It has a distinctive flavor, a sweet smell, and an astringent property [14]. It is adorned with elongated, pendulous, and cylindrical brown fruits. Fruits have septate cylindrical pods 25-50 cm long and 1.5-3cm in diameter. It contains 25-100 hard, glossy, flat, oval, light to reddish brown seeds [16]. The cylindrical pod (Figure 1C) is divided internally by thin, buff-colored transverse dissepiments. The seed has a pale endosperm with a yellow embryo. Seeds produce bright yellow pentamerous flowers with long drooping racemes [17]. The flower has a tall, pubescent calyx separated from the base, with a yellow corolla, oblong and obtuse segments, and antheriferous stamens (Figure 1D). According to Ayurvedic medicine, the seeds are considered an anti-bilious aperitif, carminative, and firm reddish wood that grows up to 40 feet in height [15].

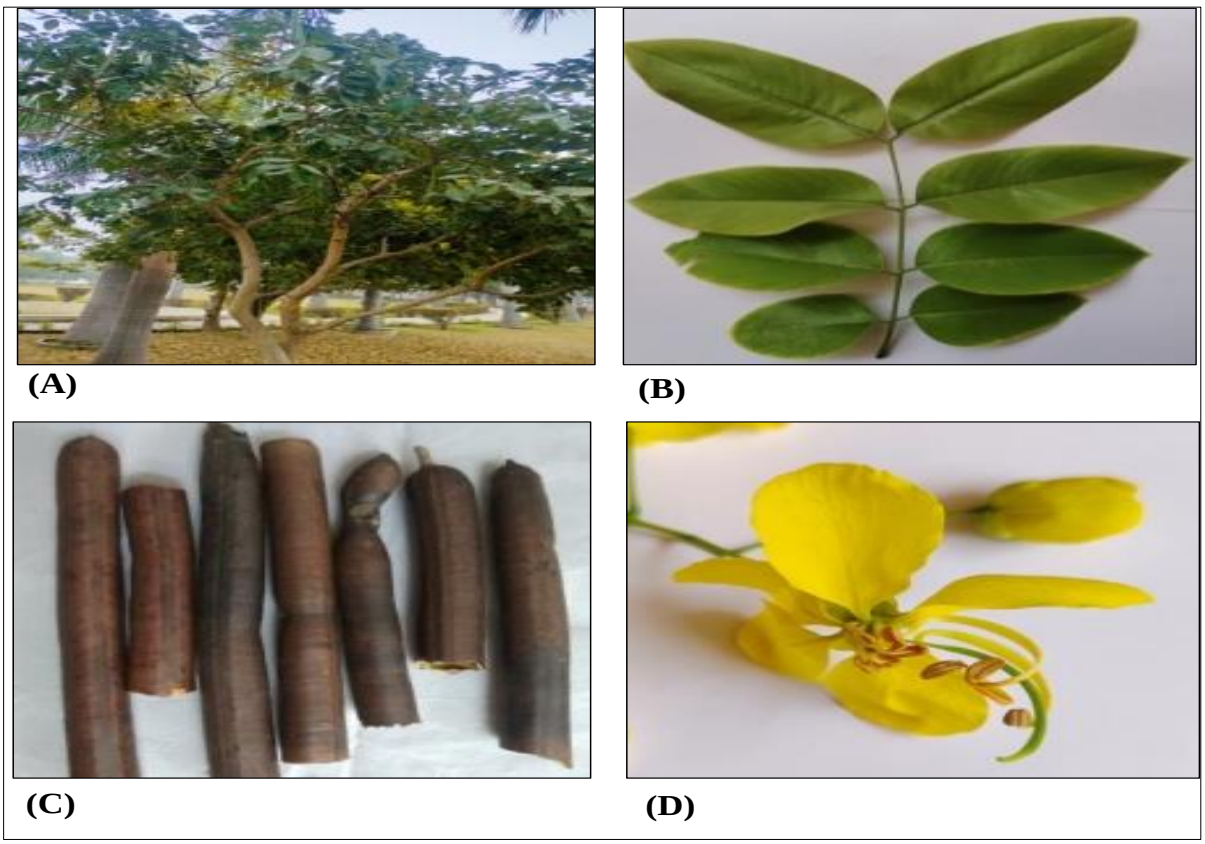


Figure 1 (A) Whole plant (B) Leaves (C) Fruits (D) Flower of *Cassia fistula*

1.3. Propagation

Cassia trees mainly propagate from seeds throughout the year. However, it is advisable to plant during the summer season. The ideal conditions for seed germination are long days with plenty of sunshine [18]. It grows on granite, stone, trap, shallow, and poor soil but thrives in well-drained, sun-exposed soil [17]. Seeds have a protracted survival period. It can maintain viability for up to three years under hermetic storage conditions of 13±2% moisture content at ambient temperature. Seedlings require adequate watering throughout their initial growth stages. The golden tree grows slowly, and leaves fall off every 9 to 10 months. Flowering and pod formation may take approximately 8-9 years to occur. The tree exhibits vigorous regenerative capabilities through coppicing and vegetative propagation via root suckers. Vegetative propagation may shorten flowering times [19].

1.4. Traditional and contemporary uses

Medicinal herbs offer a rapid, specific, sensitive, and cost-effective treatment [20]. *C. fistula* Linn. popularly known as Amulthus or Indian laburnum. It has numerous therapeutic benefits, especially in traditional medicine. It is widely used in traditional Chinese, *Ayurvedic*, and *Unani* medicine for disease prevention and therapy. British Pharmacopoeia lists this plant for its prolific and appealing therapeutic characteristics [9]. It is also grown as an ornamental plant for its aesthetically pleasing and yellow-colored blossoms. The Indian literature has documented the therapeutic properties of this plant to cure skin ailments, liver problems, pruritus, tuberculous glands, rheumatism, haematemesis, leucoderma, and diabetes [21]. Additionally, it is employed in ethnomedicine for the treatment of anorexia, cutaneous

infections, jaundice, ulcers, bronchitis, purgative, carminative, anti-pyretic, expectorant, analgesic, cathartic, antiseptic, and anti-helmintic effects [22]. It is known to be a mild laxative and carminative in Ayurvedic medicine, and it can treat syphilis, leprosy, and skin conditions [23]. Different plant parts are used throughout different regions of the world. In Pakistan, wood ash is used as a mordant in dyeing, and the pulp of the pods is useful in tobacco flavoring in Bengal [24]. It has also been used in treating skeletal fractures in Sri Lanka [25]. Leaves, bark, and seeds are used against malaria parasites in Brazil [26]. *C. fistula* is widely utilized in China as an anti-oxidant, chemopreventive, anti-inflammatory, and chemotherapeutic agent [27]. In Mexico, this plant is being evaluated as a potential source of firewood [28]. According to Indian traditional medicine, the term "Folus" is used for *C. fistula* pulp and is frequently used against infantile colic, jaundice, and leishmaniasis [6]. Additionally, fruit pulp treats constipation in cattle [29]. In the Thai medicine system, the ripe pods are a laxative drug. The soft extract is formulated into tiny tablets, boiled with water, then strained and evaporated. It is acknowledged that each part of this plant possesses medicinal properties. For instance, fruit pulp and buds are applied topically to treat abdominal pain, fever, cardiac conditions, leprosy, and gastrointestinal issues such as constipation and acid reflux. Seeds possess anti-bilious, carminative, aperitif, and laxative properties, whereas the roots have diuretic properties. Roots also treat adenopathy, tubercular glands, burning sensations, skin maladies, and leprosy. Flowers have anti-pyretic effect [30, 24]. An oral dose of *C. fistula* combined with tamarind (*Tamarindus indica* L.) aqueous extract helps with bile secretion. When combined with turpeth (*Operculina turpethum* L. Silva Manso) aqueous extract eliminates liquid and mucus from the gastrointestinal tract [31]. An oral combination of *Cassia*, sugar, saffron, and rose water treats genitourinary disorder, facilitates labor, and helps in placenta repulsion [6]. The internal and external uses of *C. fistula* L. include the treatment of jaundice, piles, rheumatism, ulcers, ringworms, eczema, and other skin conditions [32]. Many gastrointestinal issues are treated with fruit pulp as a moderate laxative [33]. The various parts (leaves, flowers, ripe fruit pulp, beans, seeds, and roots) treat various illnesses and diseases [34]. A comprehensive compilation of the traditional and contemporary uses of *C. fistula*, encompassing *Ayurvedic* and *Unani* practices, as well as ethnobotanical survey reports, as listed in Table **1**.

- *Leaves*- They have laxative, anti-periodic, emollient, and ulcer-healing properties [35]. As an external emollient and laxative, it is applied topically as a poultice to treat chilblains, edema, rheumatism, facial paralysis, and insect bites [12].
- *Stem and bark- C. fistula* bark decoction is used to treat long-term illnesses like leprosy, syphilis, menstrual problems, and heart problems in the Unani system of medicine [9,22]. The bark paste is generally applied topically (2-3 times a day) at regular intervals for 3 days to heal the region of the bug attack. To treat jaundice, an oral administration of a half-teaspoon extract is advisable [36]. The black water fever was treated with an alcoholic bark extract [35]. The bark is a source of tannin, with an approximate tannin content of 10-12%. It is utilized as a tanning agent, frequently in combination with *Senna auriculata*, in India, Pakistan, and other regions [30]. It may be an alternative to wattle (*Acacia spp.*) tannin [37].
- *Roots*- The roots are utilized to manage dermatological conditions, syphilis, leprosy, and tuberculosis [38]. The root extract can ease burning [39]. Migraine, chest pain, joint pain, and blood dysentery are treated with the roots. It is also recommended as a powerful purgative, febrifuge, tonic, and astringent. It reduced blood sugar levels by up to 30% [12]. In cases of acute toothache, a root decoction is used topically [35].
- *Flowers, fruits, and seeds*- Flowers possess a pungent, acrid flavor for purging, astringent, and cooling purposes. In addition to reducing body heat and inflammation, it treats leprosy, heart disease, liver issues, and abdominal discomfort [35]. The golden-yellow flowers are used in religious rituals in India and Bangladesh. Both the flowers and buds are edible [40]. The edible fruit tissue of *C. fistula* L. was analyzed for specific organic compounds and mineral nutrients. Potassium (K) was found to have the highest concentration among the nine macro- and micronutrients examined. Consuming around 100 g of fresh fruit would provide 100% of the US Recommended Dietary Allowances (RDA) for adults in terms of potassium. Pulp and seeds have comparatively low Na concentrations. The fruit has one of the highest amounts of calcium (827 mg per 100 g of dry matter), which could help people meet their daily 800 mg calcium needs. The fruit is an excellent source of Fe and Mn, with significantly higher concentrations than oranges, apples, peaches, pears, and apricots. The percentages of total amino acids in the pulp, including aspartic acid, glutamic acid, and lysine, were 15.3%, 13.0%, and 7.8%, respectively [38].

Additionally, the seeds contained 16.6, 19.5, and 6.6% of the same amino acids, respectively. The relatively high-calorie content of the fruit (18 kJ/g) can potentially increase the necessary daily energy intake for individuals [11]. Fruit pulp is utilized for tobacco flavoring and given to people with diabetes. It has been reported that fruit infusion can alleviate constipation, aid in the dissolution of renal stones, and treat kidney issues [35]. The fruits treat inflammatory conditions, rheumatism, asthma, chest pain, liver issues, and throat illnesses. Thai traditional medicine employs mature fruits as a laxative remedy, formulated by soaking and straining them in water [39]. Fruits have cathartic, serpent bite applications and treat asthma. Pulp is used for hepatic problems. The heated pods are applied to cold-induced swellings [12]. Seeds are used as insect repellants, alleviate biliousness, enhance appetite, and are a medication to treat diarrhea and gastritis

[38]. The mildly sweet seeds can help with constipation, gas, swelling, hunger, and fever. A dried seed has strong hypoglycemic effects [12]. Powdered seeds (5-7) are given orally to treat emetic symptoms [31]. To prevent Newcastle disease, seeds (4-6) are combined with chicken meal [41].

Table 1 Traditional and contemporary uses of *C. fistula*

Conditions	**Plant Part**	**Medical System/Regions**	**References**
Gastrointestinal system			
Infant colic	Seeds	Iraq	[42]
Diarrhea	Fruits	Pakistan	[43]
Constipation	Leaves, Seeds, Fruits	Ayurveda	[44, 45,46]
Anti-Ulcers	Leaves, Roots	Ayurvedic Medicine Systems	[46,47]
Dyspepsia	Leaves, Seeds	Ayurveda	[44,45]
Biliousness	Pulps and pods	-	[50]
	Buds	Ayurvedic Medicine Systems	[46]
	Roots	-	[47]
Eliminate liquid and mucus from the gastrointestinal tract	*C. fistula* with aqueous extract of turpeth [*Operculina turpethum* (L.) Silva Manso]	Indian Traditional Medicine	[31]
Respiratory system			
Cough	A mixture of pod's ash and salt with honey	-	[48]
	Leaves and seeds	Ayurveda	[44,45]
	Leaves	-	[48]
	Flowers	-	[49]
	Pulp and pods	-	[50]
Bronchitis	Leaves and seeds	Ayurveda	[44,45]
Chest infection	Fruits	-	[51]
Throat cancer	-	Folk Medicine	[12]
Skin Conditions			
Erysipelas	Leaves	Ayurvedic Medicine Systems	[46,52,53,]
External eruptions	Leaves	Folk medicine	[51]
Anti-aging and Skin whitening	Flowers	-	[49]
Ringworm	Leaves and fruits	Bangladesh	[54]
	Leaves and seeds	Ayurveda	[44,45]
	Roots and buds	Ayurvedic Medicine Systems	[46]
Facial paralysis, prurigo, pruritus, eczema, edema, and used as a poultice for chilblains	Leaves	-	[51]
Pain and inflammation			
Inflammation	Leaves, Bark	Brazilian herbal medicine	[46]
Rheumatism	-	Indian folk medicine	[26]

	Leaves	Ayurvedic Medicine Systems	[52,53]
	Leaves	Ayurvedic Medicine Systems	[46]
	C. fistula	India	[55]
	Pulps and pods	-	[50]
	Leaves	-	[51]
	Roots	-	[47]
Abdominal pain	Fruits	Ayurvedic Medicine System	[46]
Chest pain	Stem bark	-	[47]
Throat inflammation	Pulps and pods	-	[52]
Infectious Diseases			
Malaria	Bark, leaves, and seeds	Brazil	[26]
	Leaves	Ayurvedic Medicine Systems	[52,53]
	Pulp and pods		[50]
	Leaves	Ayurvedic Medicine Systems	[46]
Leprosy	Stem bark	-	[47]
	Fruits pulp	-	[48]
	Leaves and seeds	Ayurveda	[44,45]
	Roots, fruits, and buds	Ayurvedic Medicine Systems	[46]
Syphilis	Stem bark	-	[47]
	Root	Ayurvedic Medicine Systems	[46]
Anthrax	Fruit pulp and pods	-	[50]
Jaundice	Fruits	India	[56]
	C. fistula	Indian folk medicine	[26]
	Stem bark	-	[47]
	Leaves	-	[51]
Women's health			
Promote childbirth (Labour facilitation)	Combination of *C. fistula*, saffron, sugar, and rose water	Traditional Persian Medicine	[31]
Breast problems	*C. fistula* and goat milk mixture	-	[50]
Pregnancy constipation (safe laxative)	*C. fistula*	Traditional Persian Medicine	[57]
Traditional and cultural uses			
Ornamental plant	*C. fistula*	Nepal, Mauritius, China, South Africa, Brazil, Mexico, West Indies and East Africa	[58] [59]
Firewood	*C. fistula*	Mexico	[60]
Tanning	Bark with *Senna auriculata*	Ayurvedic Medicine Systems	[46]
Aperitif	Seeds		
carminative	Seeds		

Other medicinal uses			
Anti-pyretic	Flowers, buds and fruits	Ayurvedic Medicine Systems	[46]
	Fruits	-	[51]
	Pulp and pods	-	[50]
	Fruits	India	[55]
Heart disease	Fruits	Ayurvedic Medicine Systems	[46]
	Stem bark	-	[47]
Wound healing	Roots	-	[47]
	Flowers	-	[51]
Liver issues	Fruits pulp	-	[61]
	Leaves	Ayurveda	[13]
Tumors of the glands, abdomen, and liver	-	Folk Medicine	[12]
Anti-diabetic	Fruits pulp	-	[61]
Facial paralysis	Leaves	-	[51]
Anorexia	-	Indian folk medicine	[26]
Chemopreventive, chemotherapeutic activity, anti-oxidant	*C. fistula*	China	[27]
Bile excretion	*C. fistula* with an aqueous extract of tamarind (Tamarindus indica L.)	Indian Traditional Medicine	[31]
Bone fracture	*C. fistula*	Srilanka	[25]

1.5. Phytochemistry

C. fistula has numerous bioactive phytocomponents, including flavonoids, alkaloids, tannins, lignans, resins, fatty acids, sesquiterpenes, and anthraquinone glycosides, which contribute to its great therapeutic importance [22]. The analysis of primary phytocompounds has focused chiefly on the leaves, fruits, pollens, pods, and seeds. The protein and lipid content is 12%, the carbohydrate content is 11.75%, and the free amino acid content is 1.42% [38]. Glycosides, flavonoids, linoleic, oleic, stearic, and carbohydrates are abundant in the plant and contain tannins [33]. Rhein is an anti-carcinogenic flower component [62]. One of its constituents, i.e., lupeol, has also been shown to have anti-cancer properties [51]. Anthraquinone derivates (Sennosides A-D) are responsible for its laxative properties [6].

1.5.1. Constituents of the stem and bark

C. fistula's stem bark contains β-sitosterol, lupeol, fistucacidin (3,4,7,8,4′-pentahydroxyflavon), hexacosanol, leucocyanidin, dihydroxyanthraquinone, oxyanthraquinone, and flavonol glycosides [63]. It includes two flavonoid glycosides (5,7,4'-trihydroxy-6,8,3'-trimethoxyflavone-3-O-α-Lrhamnosyl (1—>2).-O-β-D-glucopyranoside and 5,7,3', 4'-tetrahydroxy-6,8-dimethoxyflavone-3-O-α-arabinopyranoside) and a xanthone glycoside (1,8-dihydroxy-3,7-dimethoxyxanthone-4-O-α-L-rhamnosyl (1—>2)-O--D-β-glucopyranoside26) [38]. The stem bark of *C. fistula* Linn. contains high levels of β-sitosterol and lupeol. It is also rich in phytosterols and triterpenoids. Flavonoids B and C are two novel flavonoids identified in the stem and bark of *C. fistula,* which exhibited efficacy against the plant Mosaic virus [10].

1.5.2. Constituents of the fruits, flowers, and seeds

Fruit pulp includes 1,8-dihydroxy-3-anthraquinone derivative [64], kaempferol, leucopelargonidin tetramer, rhein, fistulin, and triterpenes [65]. Additionally, the pulp has flavonid-3-ol-subordinates, arginine, protein, leucine, and carbohydrates. Its pods have kaempferol, fistulic acids, astringent, and gluten matter, whereas seeds have vernolic oil,

malvalic acid, and sterculic acid. The flower contains glycosides, essential oils, kaempferol, anthraquinones, bianthroquonones, aurantimide, and ceryl alcohol [33]. A significant study revealed that the seeds are abundant in glycerides containing oleic, linoleic, palmitic, and stearic acids as the primary fatty acids, with little caprylic and myristic acids [66]. Additional substances identified from *C. fistula* seeds include 5-(2-hydroxyphenoxymethyl)furfural, Benzyl 2-hydroxy-5-hydroxymethyl-2-(2'-hydroxypropyl) chromone, (2'S)Benzyl 2-hydroxy-3,6-dimethoxybenzoate, and Benzyl 2 β-O-d-glucopyranosyl-3,6-dimethoxybenzoate, in addition to 5-hydroxymethylfurfural, (2'S)-7-hydroxy-2-(2'-hydroxypropyl)-5-methyl chromone, and two oxyanthraquinones, chrysophanol and chrysophanein, among other substances [67]. Seed gum (7.65%) is a suspending agent for kaolin, calomel, and talc29 [38].

1.5.3. Constituents of the leaves

Leave contains free rhein, reducing sugars, coumarins, glycosides, sennosides A and B, oxyanthraquinones derivatives, and isofavoneoxalic acids. Its mature leaves contain higher anthraquinone glycosides (sennosides, rhein, aloe-emodin, physcion, and chrysophanol) than mature pods [33]. Among these compounds, rhein, in particular, has exceptional laxative qualities [10]. According to the GC-MS analysis, 18 compounds were identified, and the principal constituents were oleic acid (38.6%), 1, E-11, Z-13-octadecatriene (19.0%), palmitic acid (16.0%), and stearic acid (11.3%) [68]. Heptacosanyl-5-hydroxypentadec-2-enoate and octacosan-5,8-diol are present in leaves [69].

1.6. Pharmacological activities

The WHO reported that 80% of the global population utilizes medicinal plants based remedies [70]. Numerous studies have reported the potential of medicinal plants as a valuable resource against infectious diseases for which conventional treatments are either unavailable or ineffective. In the absence of drug and vaccine, ethno-medicine is offering broad-spectrum efficacy [71]. Notably, various plant species and their bioactive compounds have exhibited pronounced anti-microbial and anti-viral activities such as *Carica papaya* [72], *Cyamopsis tetragonoloba* [73], *Andrographis paniculata* [74], oleanolic acid isolated from *Leucas cephalotes* against dengue virus [75], *Andrographis paniculata, Tinospora cordifolia, Phyllanthus niruri* [76], silver nanoparticles of *Carica papaya* [77] against Chikungunya virus. Other studies have demonstrated that certain bioactive compounds have significant pharmacological effects, including extending the lifespan of mice with tumors, anti-diabetic properties, hepato-protective, anti-oxidant, and many other effects [78]. Numerous studies have demonstrated the pharmacological properties of *C. fistula*, as summarized in Table **2**.

1.6.1. Anti-microbial activities

Fistulin (3.5KD), a small protease inhibitor isolated from the leaves of *C. fistula,* possesses anti-microbial properties [79]. *C. fistula* Linn. crude extract exhibited larvicidal, ovicidal, and repellant properties against the vectors of the Chikungunya virus [80,81]. The evaluation of ethyl acetate extract of *C. fistula*'s flowers showed the anti-bacterial effects against *Bacillus subtilis*, *Pseudomonas aeruginosa*, and *Enterococcus faecalis* at concentrations 0.078, 0.625, and 1.25 mg/ml, respectively. The chloroform extract shows an anti-bacterial effect against *Staphylococcus aureus* (0.156 mg/ml) and *Staphylococcus epidermidis* (0.039 mg/ml). Fractionation of ethyl acetate yielded 4-hydroxy benzoic acid hydrate, confirmed by x-ray crystallography, which exhibited anti-fungal efficacy at 0.5µg/ml against *Epidermophyton floccosum* and *Trichophyton mentagrophytes* [82]. The methanolic leaves extract (10mg/ml) exhibited 100% anti-fungal activity against *Penicillium marneffei*, *Trichophyton rubrum*, and *Microsporum gypseum* [83]. The ethyl acetate fraction shows the highest activity against *Propionibacterium acnes* and *Pseudomonas aeruginosa* with MIC values of 175 and 400ppm, respectively, and MBC values of 350 and 800ppm, respectively [84]. The methanolic extract (300µg/ml) exhibited the maximum anti-oxidant activity (63.22% inhibition) and anti-fungal activity (68.07%) against *Macrophomina phaseolina*. Methanolic concentration reduced pathogen emergence by 68.07%, while aqueous extract had less significant results (60.71%) than the standard Bavistin [85]. Fistula flavones A and B, two novel 2"-ethyl-furanoflavones, and six known furanoflavones extracted from *C. fistula* stems. The structure of these compounds was confirmed using 1D and 2D NMR and high-resolution electrospray ionization mass spectrometry. The cytotoxicity of all phytocompounds was assessed in five different human tumor cell lines. A compound exhibited significant cytotoxicity towards SHSY5Y and MCF7 cells, as evidenced by its IC_{50} calculated 2.7 and 2.6 $\mu molL^{-1}$, respectively [86].

1.6.2. Anti-diabetic activity

The dose of *C. fistula* bark hexane extracts reduced a high glucose level at 0.15, 0.30, and 0.45 g/kg body weight in diabetic mice [87]. After treating alloxan diabetic rats with methanolic leaf extract for 10 hr, the blood glucose level can reduce up to 25.2% ($p < 0.001$) at 400mg/kg dose and 45.7% ($p < 0.001$) at 600mg/kg dose [88]. Another study found a significant reduction in glycemia with different aqueous fractions ($p < 0.001$) following dose administration of 300 and 500 mg/kg (at 4 and 24 hours) and 1000 mg/kg (at 1 and 4 hours). In the glucose tolerance test, the aqueous fraction decreased ($p < 0.05$) at a dose of 500 mg/kg (at 0.25 and 0.5 hours) and showed a significant increase at 1000 mg/kg dose ($p<0.001$) [89].

1.6.3. Hepatoprotective activity

The ethanol extract of *C. fistula* barks (150 and 300 mg/kg) provided hepatoprotective effects with 60.83 and 56.95 IU/L SGPT levels and 134.30 and 110.17 IU/L SGOT levels, respectively. In addition, ethanol extract (200 and 400 mg/kg) has been found to have hepatoprotective properties in CCl_4-treated mice [90]. The n-heptane leaves extract (400 mg/kg) dose protects rats' livers from damage caused by CCl_4 or paracetamol [91].

1.6.4. Anti-oxidant activity

The efficacy of three distinct solvent extracts was tested to scavenge DPPH free radicals and compared to the standard ascorbic acid. However, the extracts' DPPH radical scavenging capacities were lower than those of ascorbic acid (82.29%) at 300µg/ml. The result clearly shows that the extracts have proton-donating potential. It might be used as free radical inhibitors or scavengers, possibly as primary anti-oxidants [85]. The aqueous and methanolic bark extracts of the *C. fistula* Linn. in albino rats showed significant anti-oxidant potential by in-vitro assays (DPPH, Nitric oxide, and Hydroxyl radical-induced) [92]. Stem bark demonstrated high anti-oxidant activity in terms of O_2^- and DPPH radical scavenging ability, inhibition of peroxidation, and reducing power when compared with the 90% ethanol and methanol extract of pulp and flowers [93]. A study showed the highest anti-oxidant potency of the ethyl acetate fraction, followed by the n-hexane fraction and then the aqueous fraction of *C. fistula* pods [94].

1.6.5. Anti-helmintic and anti-leishmanial activity

The methanolic leaves extract shows inhibition and proliferation of *L. donovani promastigote* growth and intra-macrophagic amastigotes with an IC_{50} value of 43.31 ± 4.202µg/mL and 80.76 ± 3.626µg/mL, respectively. It was shown to be safe and less cytotoxic to human macrophages (CC_{50} = 626 ± 39 µg/mL) compared to miltefosine, a control drug (CC_{50} = 7.133 ± 0.65 µg/mL) [95]. A study found that *C. fistula* aqueous and alcoholic leaf extracts showed higher mortality than albendazole and worked better at greater dosages. An exposure of 50 mg/ml concentration of albendazole (10 hours) showed a 73.33% mortality rate. While alcoholic (8 hours) and aqueous extract (10 hours) of *C. fistula* leaves showed a 100% mortality rate against *Fasciola gigantica* parasites. In contrast, a 2-hour treatment showed that 50mg/ml of albendazole and aqueous extract caused 20% and 26.66% mortality. While the lowest dosage of 10 mg/ml did not cause mortality. An alcoholic extract at 10 mg/ml showed a 13.33% mortality rate [96].

1.6.6. Anti-inflammatory activity

Compared to the standard (diclofenac) groups, 6 days of oral administration of a higher dose (500 mg/kg, p.o.) of *C. fistula* methanolic leaves extract has better anti-inflammatory effects than a lower dose (250 mg/kg, p.o.). It possesses a good correlation with the therapeutic use of *C. fistula* leaves. Followed by practitioners of the *Ayurvedic* system of medicine for treating inflammatory conditions [97].

1.6.7. Anti-ulcer activity

C. fistula Linn's ethanol leaves extract at a higher concentration (750 mg/kg b.w.) shows a higher anti-ulcer effect than ranitidine (30 mg/kg b.w.) against stomach ulcers caused by pylorus ligation. The ethanolic extract at a higher dose prevents the rise in LPO and SOD with lowered catalase concentration. It also reduces gastric acid secretion, restores mucosal secretion, and protects the mucosal barrier [98].

1.6.8. Nanoparticles activity

Nanoparticles possess anti-microbial properties due to their particle size, which is a significant factor responsible for their therapeutic potential against many pathogens [77]. Nanoparticles are highly used as a drug delivery agent, biosensing, and water purification. Medicinal plants and their nanoparticles exhibit anti-microbial properties, and these plant metabolites are economically safe and effective [99]. The gold nanoparticles synthesized using aqueous extract have anti-diabetic properties [100]. A dose-dependent cytotoxic effect of biosynthesized silver nanoparticles of flower extract showed cell mortality against vero (89.7%) and MCF-7 cell line (90.5%) at 1000µg/ml doses. The IC_{50} value observed was 66.34µg/ml against vero and 7.19µg/ml against the breast cancer line [101].

Table 2 Pharmacological studies carried out on *C. fistula's* different plant parts.

Part Used	**Type of extract/ Nanoparticles**	**Activity**	**Active strains**	**Methods/ standard**	**Results/ Effective concentration**	**References**
Anti-microbial						
Leaves	Hydro-alcohol	Anti-bacterial and anti-fungal	Bacterial strains: *E. coli, P. aeruginosa, S. aureus, S. pyogenes, and* Fungal strains: *A. niger, A. clavatus,* and *C. albicans,*	Agar disk diffusion and Agar cup method/ ampicillin, chloramphenicol, ciprofloxacin, norfloxacin; nystatin and griseofulvin	Zone of inhibition observed between 11-20 mm for bacterial strains and 14-20 mm for fungal strains	[102]
Leaves	Ethanol, methanol, and aqueous	Anti-bacterial	*E. coli, S. sonnei, S. typhimurium, B licheniformis, B. subtilis, S. epidermidis,* and *S. aureus*	Agar cup method	ZOI was 94-1500 µg/ml (w/v), *E. coli* O157:H7 with highest ZOI; *S. epidermidis* has the lowest MIC value	[36]
Leaves	ZnO NPs	Anti-bacterial	*E. coli* and *S. aureus*	Paper disc diffusion/ Amoxicillin, Ceftazidime, Cefoperazone, Imipenem, and Cefixime, Erythromycin, Vancomycin, Gentamycin, Lanzolid, and Chloramphenicol	ZOI against *E. coli* (10µl) was 21 ± 0.068 and (200 µl) 44 ± 0.300; *S. aureus* (10µl) was 14 ± 0.054 and (200 µl) 32 ± 0.230	[103]
Leaves	Essential oils	Anti-fungal	*C. albicans* and *A. niger*	Micro broth dilution/Gentamicin and amphotericin B	MIC for *C. albicans* and *A. niger* was 78 and 313 µg/mL, respectively	[104]
		Cytotoxicity	Human MCF-7 breast adenocarcinoma cells	MTT assay	100 µg/mL conc. cytotoxic to 19.6 ± 11.9% cells; IC_{50} of limonene was 74.7 ± 4.1 µg/mL, and (E)-phytol was 54.3 ± 1.6 µg/mL)	

Roots	Aloe-emodin and H.V. physcion loaded microspheres of alcoholic fraction; H.V. physcion loaded microspheres of fractional alcoholic	Anti-bacterial and anti-fungal	Bacterial strains *: E. coli, P. aeruginosa, B. subtilis, S. aureus;* Fungal strain: *C. albicans*	Disc Diffusion Method/ Ciprofloxacin and Fluconazole	maximum ZOI observed with aloe-emodin containing Microsphere against *E. coli* (50mg/ml) was 21.20 mm; Physcion containing Microsphere against *C. albicans* (50mg/ml) was 16.12 mm	[105]
Leaves	Aqueous and methanol	Anti-fungal	*A. niger, C. albicans,* and *M. gypseum*	Disc diffusion method	Methanolic extract showed maximum ZOI (13mm) against *A. niger*	[106]
Flower	Methanol and ethanol	Anti-bacterial	*E. coli*, *P. aeruginosa*, *B. cereus, S. aureus*, *S. epidermidis*, *S. Typhi*, *K. pneumoniae*, and *P. mirabilis*	Disc diffusion assay/ Nafcillin, Carbenicillin, Novobiocin, Doxycycline, Colistin, Methicillin, Oxacycline	Maximum ZOI observed in ethanolic extract against *E. coli* (26mm)	[107]
Seeds	Methanol	Anti-microbial	Bacterial strains: *S. aureus, E. coli, B. thuringiensis, Salmonella, Micrococcus sp., B. subtilis;* Fungal strains: *C. albicans, and A. niger*	Disc diffusion, broth dilution, and brine shrimp assay/ chloramphenicol and Miconazole nitrate	*Micrococcus sp.* Showed maximum ZOI (29mm); MIC of anti-microbial activity range: 1.563–50.00 mg/ml; Brine shrimp showed no significant toxicity (LC_{50} = 2.11 mg/ml)	[108]
Leaves, bark, and seeds	Aqueous, Ethanol, petroleum ether, and chloroform	Anti-fungal	Fluconazole resistant and MTCC strains: *C. albicans, C. krusei, C. glabrata, C. tropicalis, C. parapsilosis,* and *C. kefyr*	Broth dilution and Agar diffusion assay	Ethanolic extract of seeds showed the highest fungicide activity due to the binding of gallic acid with lanosterol 14-alpha demethylase	[109]
Leaves, flowers,	Aqueous (hot and cold) ethanol,	Anti-microbial	Bacterial strains: *E. coli, P. mirabilis, P. aeruginosa, S. aureus,*	Agar well diffusion method	Flower extracts of acetone showed	[110]

and bark	methanol, acetone extracts		*Acinetobacter sp.;* Fungal strain: *C. albicans*		maximum ZOI (24.6mm) and MIC (6.25 mg/ml) against *S. aureus*. Aqueous extracts did not show anti-microbial activity	
Stem bark	Aqueous alcoholic (50%) and alcohol (absolute)	Anti-fungal	*S. paracitica* (NJM 8604), *S. diclina* (NJM 0005) and *A. invadans* (NJM 9701)	-	Both extracts kill the pathogens by inhibiting the growth of hyphae and zoospores. The 24-hour dose exposure of 1000-2000µg/mL was sufficient against two Saprolegnia strains, while a lower dose of 250-500 µg/mL kills both hyphae and zoospores stage of *A.invadans* NJM 9701	[111]
Leaves and bark	Methanol and dichloromethane	Anti-microbial and Brine-shrimp lethality assay	*E. coli*, *B. subtilis*, *S. aureus*, and *P. aeruginosa;* Fungal strain*: A. flavus* and *F. solani*; Larvae of brine shrimp (*Artemia salina)*	Agar diffusion, Agar tube dilution assay/streptomycin	No cytotoxicity against bacteria and brine shrimp. Methanolic extract showed anti-fungal potential because of the presence of tannins	[112]
Barks	Aqueous, ethanol, n-hexane, and ethyl acetate	Anti-bacterial	*E. coli* and *S. aureus*	Disc diffusion agar assay/ amoxicillin	Fraction of ethyl acetate showed inhibition against *S. aureus* and *E. coli* with MIC values of 0.625 and 1.25%, respectively	[113]
Leaves	Aqueous and methanol	Anti-bacterial	Bacterial strains: *S. aureus, S. epidermidis, S. pyogenes, E. coli, P.*	Agar disc diffusion	Significant suppression of bacterial	[114]

			aeruginosa, P. mirabilis, P. vulgaris and *E. aeruginosa*		proliferation (Gram-ve are more vulnerable than Gram+ve bacteria). Both extracts showed maximum ZOI against *Enterobacter aeruginosa*	
Roots	Aqueous, ethanol, chloroform, and Petroleum ether	Anti-bacterial	*S. aureus, S. faecalis, B. subtilis, K. pneumoniae, E. coli,* and *P. aerugenosa*	Broth microdilution assay/ ciprofloxacin and norfloxacin; Microplate Ala-mar Blue assay/ isoniazid	Alcoholic extract showed significant activity against *B. subtilis* with MIC of 1.6 µg/ml. Anti-tubercular activity against *M. tuberculosis* with a MIC of 12.5 µg/ml. Alkaloids and tannins plays a significant role in anti-bacterial and anti-tubercular activity	[115]
Seed		Anti-candidal and anti-fungal activity	*C. albicans (*kidney and blood Sample of *C. albicans* infected mice)	broth dilution (Time-kill assays)	The MIC of seed extract: 6.25 mg/mL. The extract (2.5 g/kg b.w.) reduced *C. albicans* growth in kidney and blood by 6-fold	[116]
Flower	Aqueous, methanol, hexane, chloroform, ethyl acetate/ 4-hydroxy benzoic acid hydrate	Anti-microbial	*B. subtilis*, *E. faecalis*, *S. aureus* (ATCC 25923), *S. epidermidis* (MTCC 3615), E. coli (ATCC 25922), *K. pneumoniae* (ATCC 15380), *P. vulgaris* (MTCC 1771), P. aeruginosa (ATCC 27853) and *Erwinia sp.* (MTCC 2760); Fungal strains: *T. rubrum* (MTCC 296), *T. rubrum* (57/01), *T. mentagrophytes* (66/01), *T. simii* (110/02), *E. floccosum* (73/01), *Scopulariopsis*	Disc-diffusion method/ Streptomycin	Gram +ve species with MIC between 0.078 and 2.5mg/ml and active against only one Gram-ve bacteria (*P. aeruginosa*: 0.625 mg/ml); 4-hydroxy benzoic acid hydrate inhibit *T. mentagrophytes* and *E.*	[82]

			sp. (101/01), *A. niger* (MTCC 1344), *B. cinerea*, *C. lunata* (46/01) and *C. albicans* (MTCC 227)		*floccosum* (MIC: 0.5 mg/ml)	
Anti-hyperlipidemic						
Bark	Methanol and ethyl acetate	Anti-hyperlipidemic and anti-atherosclerotic	Swiss albino mice (High-fat diet-induced hyperlipidemia)	-	Methanolic and ethyl acetate extract at 500mg/kg reduced triglycerides, LDL, VLDL, and total cholesterol and increased HDL. *C. fistula* bark extracts' anti-atherosclerotic efficacy may reduce myocardial degeneration and inflammation in histopathology studies	[117]
Fruit	Ethanol	Anti-hyperlipidemia	Hyperlipidemia (High-fat diet-induced mice)	Atorvastatin	Reduction of hepatic and cardiac melondialdehyde, total cholesterol, triglyceride, LDL-C, and VDL-C to normal, decreases lipid accumulation in adipocytes and increases the HDL-C level	[118]
Leaves	Aqueous	Anti-hyperlipidemic	Male Balb/c mice (High-fat diet-induced hyperlipidemia)	-	Increased the level of HDL-C and prevent elevated serum cholesterol, TG, LDL	[119]
Anti-diabetic						
Stem bark	Alcoholic	Anti-diabetic, and Anti-oxidant	Alloxan-induced diabetic rats	DPPH, nitric oxide, and hydroxyl radical assay/ gliclazide	Body weight, albumin, cholesterol, triglyceride, creatinine, and total proteins recovered to	[120]

					normal. Lowering blood glucose level. Protective effect on renal issues.	
Bark	Ethanol (95%) and ethyl acetate	Anti-diabetic	Wistar albino (Alloxan-induced Diabetic rats)	Gliblenclamide	Ethyl acetate fraction reduced blood glucose and normalized blood lipids more than alcoholic extract	[121]
Anti-inflammation						
Roots	Fraction of aloe-emodin and physcion-loaded microspheres.	anti-inflammatory	Adult male Albino Wistar rats (Carrageenan-induced paw edoema)	Diclofenac Sodium	Aloe emodin-containing microspheres showed maximum % inhibition of 76.50 % and 85.71 % at 100 and 200 mg /kg oral doses on 360 min, respectively.	[105]
Leaves	Ethanol	Anti-inflammatory and anti-pyretic	Rat paw edema (Carrageenan induced)	Diclofenac and indomethacin	In a dose-dependent manner, a dose of 250 and 500 mg/kg b.w. after 60 min. shows a reduction in TAB vaccine-induced pyrexia, while after 30 minutes, the dose of 750mg/kg lowered the vaccine-induced body temperature	[122]
Anti-cancerous						
Fruit and seeds	n-butanol and ethyl acetate	Anti-cancer	SiHa (human cervical cancer cells) and MCF-7 (breast cancer cells)	-	Bax and p53 genes were upregulated; caspase-3, 7, 10, and 9 enzyme activity	[123]

					increased, and the Bcl-2 gene was downregulated. The growth of MCF-7 and siha was inhibited, and modulated apoptosis-regulatory genes and caspase enzymes to kill cells	
Flower (Rein)	Ethyl acetate extract	Anti-cancer	COLO 320 DM (cancer cell line) and VERO (normal cells)	-	Rhein cause cytotoxicity in cancer cells at concentrations 6.25 and 12.5 µg/mL and showed minimum cytotoxicity to Vero cells	[62]
Anti-oxidant						
Fruits	Aqueous, Methanol, hexane, chloroform, ethyl acetate, and n-butanol	Anti-mutagenic, anti-oxidant	*S. typhimurium* (TA98 tester strain); NPD (direct-acting mutagen) and 2 AF (S9-dependent mutagen)	Ames assay; DPPH, NO, Superoxide anion, and Lipid peroxidation inhibition assays	Highest protection against both NPD and 2-AF. Inhibiting 81% and 64% at the conc. of 1×10^3 and 2.5×10^3, respectively; Maximum activity showed by Ethyl acetate fraction (IC_{50}= 97.01 µg/ml)	[124]
Pod	Methanol	Anti-oxidant	-	DPPH, NO, superoxide and hydroxyl radicals assay/ Ascorbic acid	Possess excellent anti-oxidant and enzymatic activities	[125]
Leaves	Aqueous	Anti-oxidant	Male Wistar rats	DPPH, reducing power, metal chelating, H_2O_2 scavenging assays/ Ascorbic acid	Presence of polyphenols responsible for anti-oxidant activity	[126]
Flowers	Aqueous, methanol, ethyl acetate, and chloroform	Anti-oxidant	-	DPPH assay, lipid peroxidation inhibition, and	Methanolic extract showed higher anti-oxidant potential due to	[127]

				reducing power/ α-tocopherol	the presence of flavonoids and phenolic compounds	
Seeds	Methanol extract	Anti-oxidant	-	DPPH, and Xanthine oxidase assay	DPPH radical scavenging of seed extract (IC_{50} of 11.07 mg/ml) showed 59.587% anti-oxidant activity and 64.56% inhibition activity	[128]
Fruit	Aqueous and ethanol	Anti-oxidant		DPPH, ABTS, Superoxide anion, Hydroxyl, Nitric oxide radical scavenging activity, Lipid peroxidation inhibition assay, Metal chelating activity	Ethanolic extract showed better anti-oxidant potential than aqueous extract	[129]
Flower	Ethanol	Anti-oxidant	Male albino Wistar strain rats (Streptozotocin-induced diabetic)	-	Restore the properties of all enzymes (GSH, SOD, CAT, and gpx). Increased level of blood glucose and HBA1c back to normal conditions. Its anti-oxidant capacity contributes to its anti-diabetogenic	[130]
Fruit pulp	Ethanol	Anti-oxidant	Swiss albino inbred mice (Stress induced by immobilisation and swimming)	FRAP and SOD/CAT/GPx/GSH/MDA assays	Increased superoxide dismutase, catalase, and glutathione peroxidase levels in the brain, heart, lungs, stomach, kidneys, and gastrocnemius muscles. Decreased glutathione and malondialdehy	[131]

					de levels compared to control drug. High phenolic and flavonoids contribute to its anti-oxidant potential	
Leaves, bark, stem and roots	Methanol	Anti-oxidant	-	DPPH assay	Bark extract showed the highest TPC, TTC, and anti-oxidant potential	[132]
Bark, pulp, and flowers	Methanol (90%)	Anti-oxidant	Thiocyanate method	-	Stem bark showed the highest anti-oxidant activity compared to leaves. The presence of chrysophanol and reducing sugars in flowers and pulp was responsible for low anti-oxidant potential	[133]
Fruit	Methanol (50%)	Anti-bacterial and anti-oxidant	*P. aeroginosae, S. aureus, S. epidermidis, S. flexineri, B. subtilis* and *E. coli*	Disc diffusion assay and Fenton reaction model/ ascorbic acid	Extract was more effective against gram-positive bacteria while less effective against gram-negative bacteria. Anti-oxidant activity was observed with an IC_{50} (TBARS inhibition%) of 1200 µg	[134]
Hepatoprotective						
Pods	Alcoholic	Hepatoprotective	Inbred Wistar albino male rats (CCl_4-induced liver damage)		Reduction in level of ALT, AST, and ALP	[135]
Leaves and bark	Aqueous	Hepatoprotective	Albino Wistar rats (carbon tetrachloride (CCl_4) induced hepatotoxicity)	-	Lowered the increased level of plasma enzyme and bilirubin increased by	[136]

					CCl4-treatment in rats	
Fruits	Crude hydro-alcoholic	Hepatoprotective	Adult male albino mice (Bromobenzene-induced liver injury)	-	The extract reduced the bromobenzene effect. It declined the serum activity of AST, ALP, ALT, direct and total bilirubin	[137]
Bark	Ethanol	Hepatoprotective and anti-oxidant	Male Wistar rat strains (Hepatoprotective); Male and female Swiss Webster mice strains (toxicity test)	Oral acute toxicity and DPPH radical scavenging assays/ Ascorbic acid	In a dose-dependent manner, 150 and 300 mg/kg can effectively reduce GOT and GPT levels to near normal. In the toxicity test, extract had LD50 values of 14.52 and 16.14 g/kg in male and female mice, respectively, making it non-toxic. DPPH radicals reduced by 56.831% at 12 µg/ml, with an IC_{50} of 10.613 µg/ml higher than ascorbic acid (4.716 µg/ml)	[90]
Bark (Catechin)	Methanol	Hypolipidemic, hepatoprotective, nephroprotective	Male albino Wistar rats (Streptozotocin-induced diabetes)	-	Catechin improves body weight and increases hemoglobin and HDL-C. Triglycerides, LDL-C, VLDL-C levels, and total protein content were decreased. Catechin recovers the function of hepatic and kidney by reducing urea, creatinine, and	[138]

					uric acid to normal conditions	
Other activities						
Leaves	Methanol	Anti-tussive	White albino mice (sulphur dioxide-induced cough)	Codeine phosphate	Compared to the standard, the extract can inhibit maximum cough reflex at 400 and 600 mg/kg by 44.44 and 51.85%, respectively	[139]
Leaves	Ethanol	Anti-ulcer	Wistar albino male rats (Pylorus ligation-induced gastric ulcer)	Ranitidine	Pre-treatment inhibits increased LPO and SOD and decreases CAT. Extract at high dose (750 mg/kg b.w.) has the highest anti-ulcer activity comparable to ranitidine	[98]
Leaves	Aqueous, Methanol, Chloroform, and Petroleum ether	Anti-acne activity	*Propionibacterium acnes*	Agar disc diffusion	Methanolic extract showed anti-acne potential at MIC 10µg/ml	[140]
Fruits	Aqueous extract	Anti-RBC sickling	Blood samples	Sodium metabisulfite test (Sickling test)	Hypoxic RBC sickling protection in HBS gene deficienct patients	[141]
Fruit pulp	Ethanol	Anti-chronic fatigue syndrome	Forced swimming induced chronic fatigue syndrome (CFS) in albino mice	Acute oral toxicity test/ imipramine	Decrease immobility, anxiety, and malondialdehyde levels. Increases catalase and locomotor activity	[142]
Flowers	Butanol	Anti-aging	Human skin fibroblast cells	Collagen kit and ELISA	Increase the synthesis of collagen and hyaluronic acid. Inhibit collagenase, MMP-2, and	[49]

					tyrosinase activity	
Pods	Hydroalcoholic	Anti-hyperglycemic	Diabetic rats (Streptozotocin-induced)	Glibenclamide	It lowered TBARS and increased pancreatic anti-oxidant indicators. Insulin secretion, pancreatic islet integrity, and anti-oxidant status improved significantly	[143]
Fruit pulp (Sun-dried and non-sun dried)	Aqueous	Laxative properties and Acute toxicity	Adult Charles Foster strain albino rats and mice	-	Sun-dried (SD) fruit pulp showed modest laxative activity and increased intestinal fluid and motility. The laxative effect may be related to the anthraquinone component, which dominates intestinal nitric oxide formation alongside cholinergic, opioid, and Prostaglandin. SD at 10g/kg oral (10 times the optimal effective dose) did not cause acute toxicity in mice. The sun-dried fruit pulp is also used for constipation treatment	[144]

1.7. Toxicology

Methanolic extract of *C. fistula* decreased the viability of human prostate cancer cell lines in a dose-dependent manner as determined by the MTT assay. Seven doses of methanol extract to a cancer cell line were administered (0.625, 1.25, 2.5, 5, 10, 20, and 30 µg). After 48 hours of treatment, the vitality of cancer cells was reduced with increasing dose. The cancer cells exhibited the lowest viability (5.06%) at a dosage of 30µg while the highest viability (5.87%) at a dosage of

20µg [145]. According to the toxicity criteria, as demonstrated by the acute toxicity test, the ethanolic bark extract fell into the non-toxic category, which found that it had LD_{50} values of 14.52g/kg and 16.14g/kg in male and female mice [90]. A study found that oral administration of bark extract prevents the development of oral squamous cell carcinoma entirely in DMBA-coated animals [51,146]. Additionally, *C. fistula* exhibits anti-estrogenic properties [147].

List of abbreviations

- *Cassia fistula* = *C. fistula*
- Thiobarbituric acid reactive substances = TBARS
- Minimun Inhibitory Concentration = MIC

2. Conclusion

A thorough literature review showed that *C. fistula* is a therapeutically crucial medicinal plant. Utilized in different parts of India, Pakistan, and western China to treat headaches, blackwater fever, asthma, blood dysentery, leprosy, diabetes, diarrhea, stomach problems, rheumatism, and inflammatory disorders. Pharmacological research on *C. fistula's* fresh plant materials, crude extract, and isolated phytochemicals supports its many traditional applications. Most of the referenced pharmacological studies focused on substantiating its conventional applications. Several research groups have investigated its traditional applications extensively, including anti-microbial, anti-diabetic, hepatoprotective, anti-inflammatory, anti-oxidant, anti-helmintic, and anti-leishmanial properties. The various parts of *C. fistula* have been used to cure multiple ailments in varied geographical regions. For example, the pulp of pods is employed in Bengal (India) to flavor tobacco, wood ash in Pakistan is used as a mordant in dyeing, and skeletal fracture therapy in Sri Lanka. The exposition for such implementation requires further phytochemicals and pharmacological investigations to use them as a future therapeutic potential. The crude extract has larvicidal and ovicidal activity. Therefore, it can also investigated for its potential against parasitic infections. The parts of *C. fistula* contain bioactive phytoconstituents like fistulin, rhein, anthraquinone glycosides, stearic acid, oleic acid, etc., hence can be explored for its absorption and metabolism. Future research in the above areas will support the clinical application of *C. fistula* in modern medicine

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest related to this review article.

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