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Cassia fistula (Golden Shower): A Multipurpose Ornamental Tree

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ABSTRACT

Cassia fistula Linn is a multipurpose, ornamental, fast growing, medium sized, deciduous tree that is now widely cultivated world wide for its beautiful showy yellow fluorescent flowers. This paper reviews the phenolic antioxidants, metal sorption, medicinal and free radical propensities of plant parts and cell culture extracts. This paper also appraises antimicrobial activities and commercial significance of *C. fistula* parts. The main objectives of present review study are to: (1) critically evaluate the published scientific research on *C. fistula*, (2) highlight claims from traditional, tribal and advanced medicinal lore to suggest directions for future clinical research and commercial importance that could be carried out by local investigators in developing regions.

Keywords: antioxidant, medicinal plant, water treatment

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INTRODUCTION

Cassia fistula belongs to the Caesalpiniaceae, a sub group of the *Leguminoseae* family and is commonly known as Golden shower, Amaltas, Indian Laburnum, Canafistula, Lluvia de Ore or Pudding-Pipe-Tree. Golden shower is a fast growing, medium sized (up to 15 m in height and 60 cm d.b.h) deciduous tree with an irregularly rounded crown that is covered in yellow fluorescent flowers from spring to mid-summer. Flowers may develop into pendent racemes up to 18 inches long followed by long cylindrical pods with the seeds imbedded in a stick brown pulp, the specific cepihet refers to these cylindrical shaped pods. The dull, green leaves of *C. fistula* are pinnate and range from 10 to 18 cm in length. *C. fistula* native to the tropical regions of Asia is widely distributed across Pakistan, India, Indochina, and Malaysia. Due to use of *C. fistula* as an ornamental and shade tree around houses, on the edges of roads and in the streets, parks, and gardens, now it has also been introduced to the tropical regions of Africa and America (Das and Tripathi 2000; Bahorum *et al*. 2005; Hanif *et al*. 2007a). Presently *C. fistula* is gaining popularity all over the world, due to its ornamental, medicinal and water purifying attributes (Kumar *et al*. 1998; Bhakta *et al*. 1999; Gupta *et al*. 2000; Adebayo *et al*. 2004; Akanma *et al*. 2004; Ilavarasan *et al*. 2005; Hanif *et al*. 2007a, 2007b). Previously *C. fistula* was not considered as an important food commodity. But now a report on the use of *C. fistula* meal as a replacement for soybean meal in practical diets of *Oreochromis niloticus* fingerlings represents that beyond its medicinal potential. *C. fistula* can also be used as a food commodity (Adebayo *et al*. 2004). However, there are a number of articles describing the medicinal potential of *C. fistula*. Antitumor (Gupta *et al*. 2000), hepatoprotective (Bhakta *et al*. 1999), anti-inflammatory (Ilavarasan *et al*. 2005; Rajeshwari *et al*. 2006), antitussive (Bhakta *et al*. 2001), hypocholesterolaemic (El-Saadany *et al*. 1991), nematicidial (Khurma and Kumar 1996), hepatoprotective (Bhakta *et al*. 1999), antioxidant (Ilavarasan *et al*. 2005; Manonmani *et al*. 2005), wound healing (Kumar *et al*. 2006), antifungal (Phongpaichit *et al*. 2004) and antifertility (Yadav and Jain 1999) activities of *Cassia fistula* extracts are now well known.

A few reports on coagulation and heavy metal uptake potential of *C. fistula* represent the water purifying poten-

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tial of this plant which can be further explored (Hanif *et al*. 2006, 2007a, 20007b). Agarwal *et al*. (1972) isolated coloring matter (identified and named as fistulic acid) from pods of *C. fistula*, which suggests this isolated plant material can be used as natural color. So far not a single comprehensive review has been compiled from the literature encompassing all the attributes of *C. fistula* in all its dimensions. We have decided to explore all versatile utilities of *C. fistula*, a life tree, in a single manuscript to highlight the nutritional, medicinal, phytochemical, pharmacological and water purifying attributes of this plant which can be economically very important in addition to its ornamental use.

GENERAL PROPERTIES AND ORNAMENTAL IMPORTANCE

Trees are important to humankind not only environmentally, economically, and industrially but also historically, spiritually and aesthetically, for they sustain human life through direct and indirect gains by providing a wide range of products for survival and prosperity. In simple words we can say that plants are life support system of nature that sustain all life forms on the earth. Ornamental plants are grown for their aesthetic look, with no particular concern for their utility. This does not preclude any particular type of plant being grown for both of these attributes. Thus *C. fistula* is typically grown as an ornamental plant in gardens, but may also be grown as a firewood source and medicinal plant to produce drugs for folk-use and for indigenous cultures (Anonymous 1994). *C. fistula* was found as suitable candidate for planting it along roadside, lane, streets, schools, institutions, office complexes, residential areas and parking spaces for controlling, air and noise pollution in addition to its ornamental and medicinal use (Anonymous 2005). The infant's first nourishment called as gootlie given in Indo-Pak region is composed of *C. fistula* (as aperient) with sugar, and distilled water of aniseed. The sap of *C. fistula* leaves have a purgative action on the digestive organs of grazing animals like goats, cows and buffalo, and thus it is also well suited for planting on wastelands (Seth 2004). The ornamental value of *C. fistula* is due to flowering crown from May to August. Due to crown formed by its colorful pale yellow to golden flowers arranged in panicles, *C. fistula* is known as king of ornamental plants. The striking long cylindrical pods produced from pretty yellow flowers. The fruits ripen (linear-cylindrical, 30 to 50 cm long, 1.5 to 1.7 cm in diameter, transversally septate, dark brown to black, and indehiscent when ripe) in the months of April and May. Outside its habitat the season for flowering and fruit ripening varies. The seeds are obovate-ellipsoid, biconvex in cross section, ventrally flattened, 7.5 to 10.0 mm long, 6.0 to 7.5 mm wide, and 2.5 to 3.0 mm thick. The seed coat is light brown, smooth, shiny, and cartaceous with fracture lines (Holdridge and Poveda 1975; Isley 1975; Irwin and Barneby 1982). When stored at room temperature viability of seeds can be up to 1 year. To keep seeds live for longer period, they must be placed in sealed plastic, glass, or metal containers in cold chambers at a temperature of 5 to 6°C. The seeds stored in a cold chamber after 1 year can still germinate. However, there have been no accurate assessments of this practice. To overcome mechanical latency of seeds to germinate because hard seed coat, seeds could be soaked in boiling water for 5 min before planting to stimulate germination. *C. fistula* can be subject to mildew, leaf spot leaf blight, leaf rust, seedling wilt and root diseases. These dieases can be effectively controlled by following cultural practices, application of bio-control agents, fungicides etc. *C. fistula* Teak defoliators such as *Hyblea puera*, *Eutectona machaeralis*, *Ascotis selenaria*, *Tephrina pulinda* and *Epicrocis lateritialis* can be effectively controlled by aqueous and organic fractions of *Acacia nilotica* flowers, pods and twigs even in lower concentrations (0.25-0.50%) (Indian Council of Forestry Research and Education (ICFRE), 2002-2003).

CALLUS CULTURES

Though *Leguminosae* species are known for their recalcitrant nature, however some successful attempts have been made on *in vitro* organogenesis of *C. fistula, C. siamea* (Gharyal and Maheshwari 1990) and *C. alata* (Fett-Neto *et al*. 2000). There is limited literature on cultivation, genetic improvement and *in vitro* regeneration of *C. fistula*. Regeneration *via* calli has been the potent source of producing somaclonal variants in plants and thus the improvement of the species. Many Cassia plants have been propagated through calli, e.g. *C. angustifolia* (Agrawal and Sardar 2006), *C. senna* (Shrivastav *et al*. 2006) and *C. acutifolia* (Nazif *et al*. 2000). However studies still should be aimed to develop a callus mediated plant regeneration system for *C. fistula.* A polyphenoilc production enhancement correlated with an increased *C. fistula* in the culture media of three-year-old calli initiated young leaves was observed by Neergheen and Bahorun (2002) on the incorporation of L-phenylalanine up to concentration of 100 mg/L. At 100 mg/L L-phenylalanine maximal increase in growth (0.857 g of dry wt) and optimal total phenol (5.044 g/ 100 g dry wt) and proanthocyanidin synthesis (3.417 g/100g dry wt) were observed. At the same concentration, total phenolic and total proanthocyanidin overall increase was 23, 21 and 61% in comparison to control. In a study Ahuja *et al*. (1988) isolated chrysophanol and physcion from the non-differentiating callus cultures of *C. fistula.* Shah *et al*. (1978) observed the superiority of sucrose over other carbohydrates both for the growth of the cells and for the maximal production of phenolic compounds. Synthesis of phenolics was found limited to sucrose availability. The patterns of peroxidase and phenylalanine ammonia-lyase (PAL) activities were examined and the development of the enzyme activities and synthesis of polyphenols were also related.

Plant tissue cultures are gaining importance as industrial biosynthetic sources of useful secondary products (Zenk *et al*. 1977; Dornenburg and Knorr 1997; Bourgaud *et al*. 2001; Bahorun *et al*. 2002). Subbaiah *et al*. (1974) studied the influence of sucrose, 2,4-D, kinetin and giberillic acid under varied light conditions on the production of polyphenolics in *C. fistula* callus cultures. Inhibition of polyphenol synthesis and 2,4-D and kinetin when applied at supraoptimal levels was observed at higher levels of sucrose. It was also noted that 2,4-D and kinetin strongly influenced initiation of polyphenol production and carbohydrate level in the medium strongly affected the accumulation of polyphenol. Shah *et al*. (1976) reported that the polyphenol accumulation in *C. fistula* callus cultures was dependent on exponential growth phase. An investigation on the undifferentiated *C. fistula* callus cultures has indicated that chrysophanol and physcion are the main anthraquinone constituents of the culture. Babbar and Maddan (1981) observed that *C. fistula* cell cultures infected by an animal virus (Ranikhet Disease Virus, RDV) showed a surprising production of interferon-like antiviral factors. Aukhez *et al*. (2001) conducted studies using principles of magnetobiophysics (known as magnetotropism when effect of an imposed magnetic field on plant life is studied by applying the effects of imposed continuous North and South magnetic fields (1 milli Tesla) on the growth of callus cultures of *C. fistula* and their polyphenolics contents. They observed that the northern pole magnetic field exposed callus cultures and control cultures showed a similar growth pattern with an average decrease of total phenolic (24%) and proanthocyanidin (23%) production. However, southern pole treated calli produced more total phenolics (24%) and proanthocyanidins (31%) than controls with a lower biomass production.

PHYTOCHEMISTRY

The chemical constituents of *C. fistula* seeds and roots were extensively studied due to their medicinal importance. However need still remains for the less studied chemical constituents of *C. fistula* stem bark and leaves. Traditionally *C.*

fistula stem bark was used in some folk medicines and for dying of cotton clothes in Pakistan. Presently Hanif *et al.* (2007a) described the biosorptive potential of *C. fistula* stem bark and leaves but the main constituents are still to be described. The chemical constituents present in seeds of *C. fistula* were determined to be: terpenes, galactomannan, fatty acids, glycosides, aloin, barbaloin, flavone glycoside, anthraquinones, chrysophanol, chrysophanein, glycerides metals, amino acids, hydrocarbons, chromones, flavonoides, alkaloids, sterols, alcohols, sucrose and proanthocyanidins. Chowdhury *et al.* (1987) found that due to low oil contents (1.1-6.5%) *C. fistula* seeds could not be exploited as a commercial oil source. However due to their high protein content seeds could be use as food additives. They also found that oils were rich in palmatic, oleic and linoleic acids. Other authors also studied the fatty acid composition of *C. fistula* seed oil. Farooq *et al.* (1956) found that *C. fistula* seed contained the following percentages of fatty acids: palmatic (16.0%), lignoceric (5.2%), oleic (30.7%) and linoleic (48.1%). These authors did not detect stearic acid in seed oil. However, Sayeed *et al.* (1999) found that stearic acid (14.33%) is one of the major fatty acids present in *C. fistula* seed oil. The other major fatty acids detected in *C. fistula* seed oil analyzed by gas liquid chromatography (GLC) were linoleic (42.42%), oleic (29.62%) and palmatic (11.14%) fatty acids. In addition to these, caprylic (0.76%) and myristic (1.44%) acids were also found to be present in minor amounts. El- Sayyad *et al.* (1985) found that *C. fistula* seed oil is semi-drying in nature and contained too much free fatty acids, waxes and hydrocarbons to be used for food. Sayeed *et al.* (1999) fractionated golden color seed oil of *C. fistula* into mono (0.91 to 0.98%), di (2.51 to 3.32%) and tri (89.16 to 91.01%) glycerids by silicic acid column chromatography depending upon the areas from where seeds were collected. They also carried out fractionation of extracted lipids into natural lipids (89.80%), glycolipids and phospholipids by the same method. Saturated and unsaturated fatty acids present in oil varied from 23.79 to 28.20% and 63.28 to 66.71%, respectively, depending on areas.

Misra *et al.* (1997) isolated a new diterpene 3β-hydroxyl-17-norpimar-8(9)-en-5-one along with 26-methylheptacosanic acid from *C. fistula* pods. Fistulic acid is the main component of coloring matter from the pods of *C. fistula*. The structure of fistulic acid has been tentatively assigned to be 1,4-dihydroxy-6, 7-dimethoxy-2-methylanthraquinone-3-carboxylic acid by Agrawal *et al.* (1972). The galactomann of the seeds of *C. fistula* is composed of 77.14% D-mannose and 22.86% D-galactose. Yadava and Verma (2003) isolated bioactive flavone glycoside named 5,3′,4′-tri-hydroxy-6-methoxy-7-o1-l-rhamnopyranosyl- (1-2)-*O*-β-D-galactopyranoside which showed anti-microbial activity from the seeds of *C. fistula*. Proanthocyanidins containing flavan-3-ol (epiafzelechin and epicatechin) units were isolated from *C. fistula* pods by Kashiwada *et al.* (1990). A prenylated anthraquinone structure elucidated as 1,3-dihydroxy-6,8-dimethyl-2-isoprenyl anthraquinone was isolated from *C. fistula* seeds by Das and Tripathi 2000. *C. fistula* seed is used in folk medicine to treat diarrhea and gastritis; it is also an insecticide (Kan 1975).

While studying the antidiarrhoeal components of *C. fistula*, Kuo *et al.* (2002) isolated four new compounds: 5-(2-hydroxyphenoxymethyl)furfural, (2'*S*)-7-hydroxy-5- hydroxymethyl-2-(2'-hydroxypropyl)chromone, benzyl 2-hydroxy-3,6-dimethoxybenzoate, and benzyl 2β-*O*-D-glucopyranosyl-3,6-dimethoxybenzoate, together with four known compounds, 5-hydroxymethylfurfural, (2'*S*)-7-hydroxy-2-(2'-hydroxypropyl)-5-methylchromone, and two oxyanthraquinones, chrysophanol and chrysophanein, were isolated and identified from the seeds of *C. fistula*. Raie and Zaka (1991) showed that *C. fistula* seed oil contain 1.6% nonsaponifiable material which on further separation showed hydrocarbons ($C_{18:0}$-$C_{32:0}$) (43.2%) in addition to alcohols ($C_{12:0}$-$C_{28:0}$) (39.2%) and unidentified material (18.5%). Barthakur *et al.* (1995), while studying the proximate composition, found that the protein and energy value of pod pulp of *C. fistula* was one of the highest of the available data for 95 fresh, canned or dried fruits. Souci *et al.* (1986), while studying the mineral macro-nutrients of *C. fistula* pods found that K, Ca, Fe, Cu, Mn, Zn, were higher in *Cassia* fistula fruit than in the five common fruits such as, apple, apricot, peach, pear and orange. Same authors also noted that the concentration of the 17 amino acids (Ala, Arg, Aso, Cys, Glu, Gly, His, Ile, Leu, Lys, Met, Phe, Pro, Ser, Thr, Tyr and Val) were always more concentrated in the seeds than in the pulp or shell. Finally these authors concluded that the fruit of *C. fistula* is of high quality, and could be explored to fulfill the nutrient and energy requirements of Assam (India) people. Sen and Shukia (1968) found that *Cassia fistula* stem bark is a potential source of lupeol, β-sitosterol and hexacosanol. It was reported that rhamnetin 3-*O*-gentibioside is present in *C. fistula* roots (Vaishnav and Gupta 1996).

MEDICINAL AND PHARMACOLOGICAL ATTRIBUTES

According to the World Health Organization (WHO), traditional medical practices are an important part of the primary health-care delivery system to a 3.5 billion people in the developing world. Most developing countries have adopted traditional medical practices as an integral part of their culture (World Health Organization 2007).

C. fistula, the Golden shower is an important medicinal plant in addition to its ornamental use. Several reports on the hepatoprotective, antioxidant, anti-inflammatory, antitussive, antifungal, antibacterial, nematicidal, wound healing, antifertility, hypocholesterlamic, laxative, antifertility and antitumor activities have been extensively published. The effects have mainly been attributed to the presence of alkaloids (Asseleih *et al.* 1990), a triterpene derivative (Misra *et al.* 1997), anthraquinone derivatives (Kaji *et al.* 1968; Mukhopadhyay *et al.* 1998), and polyphenolics comprising flavonoids (Narayanan and Seshadri 1972; Gupta *et al.* 1993), catechins, and proanthocyanidins (Narayanam and Seshadri 1972; Morimoto *et al.* 1988; Gupta *et al.* 1993; Kashiwada *et al.* 1996). Monif *et al.* (1992) during their studies on the use of *C. fistula* seeds' galactomannan as a potential binding agent for pharmaceutical formulation found that *C. fistula* seed germ exhibit overall superiority in binding properties when compared to conventional binders like gum Arabic, gum tragacanth, sodium CMC and gelatin. The medicinal efficacies and pharmacological activities ascribed to various parts of *C. fistula* are comprehensively described below.

ANTIOXIDANT AND ANTI-INFLAMMATORY ACTIVITIES

Sufficient evidence is available to conclude that excessive free radical production and lipid peroxidation are actively involved in the pathogenesis of a wide number of diseases including diabetes (Kakkaar *et al.* 1995; Viana *et al.* 2000; Gorogawa *et al.* 2002; Spitaler *et al.* 2002; Manomani *et al.* 2005), cardic and cerebral ischemia (Keller *et al.* 1981), atherosclerosis (Parthasarathy *et al.* 1998), carcinogenesis (Kamat and Devasagayam 2000), neurodegenerative (Perry *et al.* 2000) and rheumatic disorders (Hannien *et al.* 2000), and that they are also major contributors to the aging process (Hu *et al.* 2000; Khodr and Khalil 2001). It is a well known fact that polyphenolics (Hertog *et al.* 1993) such as flavonoids (Salah *et al.* 1995), anthraquinones (Yen *et al.* 2000), anthocyanidins (Siddhuraju *et al.* 2002) and xanthones (Minami *et al.* 1994) possess remarkable antioxidant activities, and that these are present quite commonly in the *C. fistula* family, the *Leguminosae*. Obviously, there have been a number of reports on the antioxidant properties of *C. fistula* extracts. Luximon-Ramma *et al.* (2002) studied the antioxidant activities of phenolic, proanthocyanidin, and flavonoid component in extracts of *C. fistula*, extracted first with acetone/water (70:30 v/v) and finally with methanol (100%). The total phenolic, proanthocyanidin, and flavonid contents, and the antioxidant activities of fresh vegetative and reproductive parts of *C. fistula* were determined using the Trolox equivalent antioxidant capacity (TEAC) and ferric reducing antioxidant power (FRAP) assays. The antioxidant activities were found to be strongly dependant with total phenols in all organs and with proanthocyanidins in reproductive organs. Pods showed the maximum antioxidant activity. It was also concluded from the study that the reproductive parts of *C. fistula* have more antioxidant power in comparison to vegetative parts. The antioxidant properties of 90% extracts of leaves and 90% methanol extracts of stem bark, pulp and flowers of *C. fistula*, regarding their antioxidant power were ranked in following order: stem bark > leaves > flowers > pulp. The antioxidant activities of extracts were well correlated with total phenolic contents of extracts. Siddhuraju *et al*. (2002) found that low antioxidant activity of flower and pulp extracts were due to the presence of chrysophanol and reducing sugars (peroxidants) that dominate the antioxidant compounds present in the fractions. Antioxidant activities of the aqueous and methanolic fractions of *C. fistula* bark showed significant radical scavenging by inhibiting lipid peroxidation initiated by CCl_4 and $FeSO_4$ in Wistar albino rat liver and kidney homogenates. An acute toxicity study with extracts showed no sign of toxicity up to a dose level of 2000 mg/PO (Ilavarasan *et al*. 2005). In that study, an aqueous extract of *C. fistula* flowers was screened for their antioxidant effect in alloxan-induced diabetic rats. From the study, it was concluded that ACF-treated diabetic rats showed a promising decrease in peroxidation products viz. thiobarbituric acid reactive substances, conjugated dienes, and hydroperoxides. The decreased activities of key antioxidant enzymes such as superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase and glutathione in diabetic rats were brought back to a near normal range upon ACF treatment (Manomani *et al*. 2005). While studying the inhibition of leukotriene biosynthesis and lipid peroxidaton in biological models using *C. fistula* extracts, Kumar and Müller (1998) found that the methanol extract of its fruit inhibited the 5-lipoxygenase catalyzation of leukotriene B_4 in bovine polymorphonuclear leukocytes with an IC_{50} value of 38 µg/ml and in bovine brain phospholipids liposomes induced with 2,2′-azo-bis-(2-amidinopropane) dihydrochloride (AAPH) was inhibited with an IC_{50} value of 40 µg/ml.

ANTIBACTERIAL, ANTIFUNGAL, WOUND HEALING AND NEMATICIDAL ACTIVITIES

Significant antimicrobial activities of *C. fistula* are the basis of its folkloric use in the treatment of some diseases as broad-spectrum antimicrobial agents. This fact probably is the basis of the use of *C. fistula* by the people in developing countries against a number of infections. Ali *et al*. (2003) purified three lectins named CSL-1, CSL-2 and CSL-3 from *C. fistula* seeds and tested them against 14 pathogenic bacteria: *Bacillus subtilis*, *Bacillus megaterium*, *Streptococcus β-haemolyticus*, *Strep. aurens*, *Sarcina lutea*, *Shigella sonnei*, *S. shiga*, *S. boydii*, *S. flexneriane*, *S. dysenteriae*, *Escherichina coli*, *Klebsiella speries*, *Salmonella typhi* and *Pseudomonas aervginosa*. The first five bacteria are Gram-positive while the remainder are Gram-negative bacteria. The lectin CSL-3 was found to be effective against all bacterial strains. CSL-3 showed strong activity against *Bacillus megaterium*, *Streptococcus β-haemolyticus* and *Shingella boydii*. Both CSL-2 and CSL-1 showed poor activity against most of the bacterial strains except against *Streptococcus β-haemolyticus*. In addition to this CSL-1 was also effective against *Sarcina lutea*. All lectins affected significantly the mortality rate of brine shrimp (*Artemia salina*). In another study on the antibacterial activity of *C. fistula*, the dealcoholized and aqueous extracts of pulp and seeds of *C. fistula* were tested against *Staphylococcus aureus*, *S. albus*, *Micrococcus citreus*, *Corynebacterium diphtheriae*, *Bacillus megaterium*, *Salmonella typhosa*, *S. paratphi*, *S. schott* and *E. coli*. The dealcoholized seed fraction inhibited all organisms but to a lesser degree than dealcoholized pulp extracts. Alcoholic seed fractions were active only against *S. typhosa* and *C. diphtheiae* (Patel *et al*. 1956). While studying the antimicrobial activity of various plant extracts by a streaking method, *C. fistula* fruit extracted using dichloromethane and methanol (1:1 v/v) exhibited significant microbial activity against *Bacillus cereus* var. *mycoides*, *Bacillus pumilus*, *Bac. sabtilis*, *Bordetella bronchiseptica*, *Micrococcus luteus*, *Staphylococcus aureus*, *Staph. epidermidis*, *E. coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Streptococcus faecalis*, *Candida albicans*, *Aspergillus niger* and *Saccharomyces cerevisiae* (Kumar *et al*. 2006). Phongpaichit *et al*. (2004) investigated the crude methanol extract from leaves of *C. fistula* for its antifungal activities on three pathogenic fungi viz. *Microsporum gypseum*, *Trichophyton rubrum* and *Penicillium marneffei*. The leaf extract was found to be the most potent inhibitor of *P. marneffei* with an IC_{50} of 0.9 mg/ml. Microscopic observations revealed that after treatment with leaf extract the hypae and macrocondria shrunk and collapsed, due to cell fluid leakage.

A great deal of research efforts has been directed toward the control of root-knot nematodes; *Meloidogyne* sp. is the most damaging of plant parasitic nematodes. The use of many hazardous chemical nematicides has been banned due to their acute and chronic toxicity to human as well as to other life forms. The necessity to use eco-friendly chemicals for nematode control forced Khurma and Mangotra (2004) to screen some *Leguminosae* seeds for nematicidal activity. During their study these authors found that aqueous *C. fistula* seed extract (25 g/100 ml), when used at a 1:10 dilution, resulted in a *Meloidogyne* mortality rate of above 90%. *C. fistula* seeds in the past were recognized as strongly nematicidical in different studies (Khurma and Kumari 1996; Khurma and Chudhary 1999). Wound infections caused by microorganisms are the most common in developing countries because of poor hygienic conditions. Due to adverse effects in the human body and developed resistance of pathogens to antibiotics targeted against them, plant extracts containing biologically active compounds have been gaining recent attention (Mertz and Ovington 1993; Essawi and Srour 2000). In this regard, the *C. fistula* leaf fraction was tested for its wound healing potential in rats and the results were very promising (Bhakta *et al*. 1998; Kumar *et al*. 2006).

ANTITUSSIVE AND HEPATOPROTECTIVE ACTIVITY

The leaf juice of *C. fistula* is used in folklore to treat cough in Tripura, India. To substantiate this claim Bhakta *et al*. (1998) evaluated the antitussive effect of *C. fistula* leaf extract using methanol against SO_2-induced cough reflex in albino mice. They came to know that the antitussive activity of this extract was comparable to that of codein phosphate (a prototype, antitussive agent). *C. fistula* pods and leaves are well known for their antiallergic as well as heptoprotective effects in the North Eastern Region of India. Based on ancient practices and traditional uses of this plant as a hepatoprotective agent, the *n*-heptane extract of *Cassia* leaves was investigated for its hepatoprotectivity in rats by inducing hepatotoxicity with carbon tetra chloride: liquid paraffin (1:1). The extract showed hepatoprotective activity comparable to neutrosee (a standard hepatoprotective drug) by lowering the serum levels of transminases (SGOT and SGPT), bilirubin and alkaline phosphatase (ALP) (Bhakta *et al*. 1999, 2001).

LAXATIVE, ANTIFERTALITY, ANTITUMOR AND HYPOCHOLESTEROLAEMIC POTENTIAL

Akanmu *et al*. (2004) successfully used *C. fistula* pods' aqueous fraction as a laxative drug in their *in-vitro* studies on isolated Guinea-pig ileum with an LD_{50} of 6600 mg/kg.

This suggests the possibility of using pods as a safe substitute for unnatural or chemical drugs. The ethanolic extract of *C. fistula* pods showed an estrogenic effect in rats (Bhardwaj and Mathur 1979). Oral administration of the *C. fistula* seed fraction (a mild estrogenic agent) to mated pregnant female rats resulted in antifertility. However when same extract was administrated orally in the presence of strong estrogen, it showed antiestrogenic nature (Yadav and Jain 1999). Plant-based natural substances offering mild inherent esterogenic and antiesterogenic properties can be effectively used as non-conventional sources of contraception with less deleterious side-effects (Kirtikar and Basu 1973). The methanolic extract of *C. fistula* seed proved to be an antitumor agent in mice (Gupta *et al.* 2000). In another study albino rats fed *C. fistula* fruit powder recovered to a normal condition from hypercholesterolaemia (El-Saadany *et al.* 1991).

Other diverse activities exhibited by *C. fistula* are: The seeds are useful in jaundice (Asolkar *et al.* 1992), biliousness, skin disorders and oral soars (Bedding 1983). Other ethnomedical uses of *C. fistula* include its anti-diarrhoeal and anti-dysentery activities (Manandhar 1989). Hot water fractions of *C. fistula* proved to be useful in the treatment of uterine, menstrual disorder and fever, while the butanol extract of *C. fistula* residue from a 70% alcohol fraction exhibited anti-viral effect (Kaji *et al.* 1968; Sen and Shukla 1968).

C. FISTULA AS A NATURAL DYE SOURCE

Khan *et al.* (2004) conducted studies to extract natural dye from *C. fistula*. The extracted dye was developed in 32 different shades and used for dyeing mordant wool with alum, chrome, copper and iron salts. The coloring present in pods of *Cassia fistula* was named as fistulic acid (1,4-dihydroxy-6,7-dimethoxy-2-methylanthraquinone-3-carboxylic acid) by Agarwal *et al.* (1972).

C. FISTULA AS A POTENTIAL SOURCE OF FOOD AND COMMERCIAL GUM

C. fistula meal has been evaluated by Adebayo *et al.* (2004) as a replacement for soyabean meal in practical diets of *Oreochromis niloticus* fingerlings. From the results of their study, it was revealed that the growth performance and nutrient utilization of *Niloticus* fingerlings fed up to 170 g/kg of *C. fistula* seed (roasted at a temperature of around 80°C for 20 min to reduce moisture contents as well as antinutrient contents) as meal could be substituted for soyabean meal in practical diets without compressing growth. During their studies Kapoor and Farooqi (1993) found that *C. fistula* seeds can be used as a potential source of commercial gum and that the seed gum possesses nonionic properties comparable to commercial glactomannans and thus could be utilized for industrial purposes.

C. FISTULA AS A BIOSORBENT

Hanif *et al.* (2007a) used different parts of *C. fistula* biomass as a less expensive biosorbent for the removal of nickel from hazardous aqueous streams. The functional groups present on the cell surface of *C. fistula* involved in nickel biosorption included carboxyl, carbonyl, alcoholic and amino groups. Hanif *et al.* (2007b) further explored the ability of *C. fistula* biomass to remove nickel from seven different industrial effluents collected from Faisalabad, a well-established industrial city of Pakistan. The nickel sorption capacity in all cases was found to be more than 90%. They evaluated the whole study by concluding that metal-sorption equilibrium was much faster in the case of industrial effluents in comparison to synthetic effluents.

C. FISTULA AS A NATURAL COAGULANT

Hanif *et al.* (2006), while studying the coagulant behavior of *C. fistula* concluded that its pods contain a natural polyelectrolyte that can be used as a coagulant to clarify turbid textile industry waste water. Furthermore, the use of *C. fistula* as a natural coagulant produced substantial improvement in aesthetic and microbiological quality of wastewater from textile units.

FUTURE PROSPECTS

Medicinal, food, water purifying and commercial utilization suggest that *C. fistula* is a life tree. The healing potential of *C. fistula* provides a scientific rationale for the traditional use of this plant in the management of infected dermal wounds and should be further investigated to treat infected wounds without using synthetic wounds. The current review study provides some useful insight into the antioxidant potency of different vegetative and reproductive parts of *C. fistula*. However, it is strongly suggested that the isolation of bioactive components in the extracts should be isolated, which would certainly help to ascertain the individual use of compounds. These isolated compounds could be further exploited for use by the food and pharmaceutical industries. Anti-inflammatory activities of aqueous and methanol extracts of *C. fistula* bark, when assayed in Wistar albino rats, were found to possess significant anti-inflammatory effect in both acute and chronic models. These promising results were confirmed. The results concluded that *C. fistula* bark extracts (150 mg/kg b. wt. of male albino rats) possess anti-inflammatory activity as compared to the standard drug diclofenic (5 mg/kg b. wt. of male albino rats). The active constituents, exhibiting anti-inflammatory activity should be isolated for pharmaceutical use. *C. fistula* has many important utilities such as medicinal, food, coagulant, biosorbent and as a natural dye source apart from its use as a beautiful ornamental tree. *C. fistula* is an important source of naturally occurring bioactive compounds such as polyphenolics, flavonoids and anthraquinones. Traditional medicinal systems have become part of lives of peoples in developing countries. Due to importance of traditional medicines, it has become important to evaluate the phytochemical compositions and biological activities need to be well understood and how the bioactive components in plant extracts affect cellular signaling processes and modulate oxidative stress mediated responses. Finally it can be concluded that integration of traditional medicine into the primary health systems require both demonstration of clinical and biochemical evidence of efficacy.

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