ID: 578

Potentials of *Senna tora* (L.) Roxb. as Source of Functional Food and Bioactive Compounds with Antioxidant, Antimicrobial and Anti-Inflammatory Activities

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Abstract

Senna tora (L.) Roxb. is an important ethno-medicinal plant from time immemorial. Different parts of the plant have found applications in Chinese and Ayurvedic medicine. There is a reputation for the food application and therapeutic properties of the plant's leaves and seeds. The purpose of this review is to ascertain the potential of *Senna tora* (L.) Roxb. as a source of functional food as well as drug candidates against oxidants, inflammation, and microbial infection. Based on the previous literature, the discoveries of bioactive compounds including phenols, flavonoids, tannins, terpenoids, saponins, steroids, alkaloids, glycosides and reducing sugar seem to rationalize the proposed use of *Senna tora* (L.) Roxb. as antioxidant, anti-inflammatory, and antimicrobial agents. Furthermore, the young leaves are cooked and eaten as a vegetable or cook with pulses while the roasted seeds are used as a substitute coffee, also, the seed gums are used as thickener in foods. It can be concluded that *Senna tora* (L.) Roxb. is rich in numerous bioactive compounds that have the potential to fight against oxidants, inflammation, and microbial infection as potential drug candidates. In addition due to its numerous bioactive compounds, *Senna tora* can find profound application in the development of functional foods and nutraceuticals.

Keywords: *Senna tora (L.) Roxb. Antioxidant activity, Anti-inflammatory activity, Antimicrobial activity, Functional Food*

Introduction

Nature bestows medicinal plants on humans as a gift to help them on their journey toward better health. Natural plant products have been identified and used by humans from time immemorial as food and a primary source of therapeutic medications (Adnan et al., 2021; Siddiqui et al., 2022). They continue to be an abundant source of well-known and potent bioactive compounds that are capable of being employed as medications right away (Siddiqui et al., 2022). There are numerous examples of plant-based medications, like antimicrobial as nicotine, antioxidant as nordihydroguaiaretic acid (NDGA), anticancer as vinblastine, bleomycin, paclitaxin, and taxol, and anti-inflammatory as aescin and capsaicin, cardiotonic as acetyldigoxin, and antiparkinsonism as L-dopa, etc (Adnan et al., 2021; Kabir et al., 2020). Their application is advocated within the frameworks of Ayurvedic, Unani, Siddha, Homeopathic, and other medical systems (Adnan et al., 2021). They have a significant impact on a great number of human lives as traditional treatments for many illnesses, including rheumatism, bronchitis, burns, itches, leprosy, colds, roundworm infection, hemorrhaging in wounds, diarrhea, and others (Adnan et al., 2021; Elasbali et al., 2022). Even though many pharmaceuticals derived from plants have been found, more research into novel bioactive compounds is still needed to increase the number of pharmacological alternatives accessible and find less harmful drugs with better efficacy (Alreshidi et al., 2020; Awadelkareem et al., 2022). In order to reduce the risk of cellular damage or tissue injury, inflammation, microbial infection, and related disorders caused by free radicals, one of the most active research areas is the search for highly antioxidant, anti-inflammatory, and antimicrobial phytochemical compounds. Although synthetic antioxidants are available for the treatment of oxidative stress-mediated oxidant-induced diseases and disorders, they have associated health risks and severe adverse effects (Lourenco et al., 2019). Nonsteroidal anti-inflammatory drugs (NSAIDs) are used for treating inflammation, but they have a number of negative side effects, such as heartburn, nausea, vomiting, and gastrointestinal ulcers (Sostres et al., 2010; Philipsborn et al., 2020). Antimicrobials are becoming less effective, which makes treating conditions like gonorrhea, pneumonia, TB, blood poisoning, and foodborne illnesses harder and often impossible. The emergence and global dissemination of new resistance mechanisms pose a danger to our ability to cure prevalent infectious diseases (Lomazzi et al., 2019). Furthermore, the bulk of antibiotics on the market today have dangerous side effects, such as anaphylaxis, dermatological cross-reactivity, life-threatening immune-related fallacious effects, hypersensitivity, and altering the body's normal microbiota, which can affect normal physiological processes and increase susceptibility to viral diseases like the flu (Bradley et al., 2019). As a result, the "back to nature" approach has been increasingly popular in recent years. Numerous compounds derived from plants have been developed and approved for use as antimicrobial, anti-inflammatory, and antioxidant potential therapeutics (Furst et al., 2014; Savoia, 2012; Subramani et al., 2017). Therefore, the continuous exploration of antioxidant, anti-inflammatory, and antimicrobial phytochemicals plays a key role in finding a feasible course of action that is safe and that lowers the adverse effects induced by chemotherapy.

Senna tora (L.) Roxb. (Syn *Cassia tora*) is a yearly foetid herb that belongs to the family Fabaceae and commonly propagates in barren land as a monsoon wild plant in humid countries (Jain & Patil, 2010; Singh *et al.*, 2013; Maneenoon et al., 2015; Pawar & Lalitha, 2015). It is known as foetid cassia/sickle pod/sickle senna in English (Jain & Patil, 2010; Maneenoon et al., 2015; Pawar & Lalitha, 2015; Mishra & Moses, 2018). It is one of several wild medicinal food plants (Hanh et al. 2021). Though it is being consumed by several ethnic communities, it is still considered to be an unexplored plant group with potential health advantages. *Senna tora* (L.) Roxb. plant is still underexplored, and we need to document it to create livelihood options and fight against food and medicinal problems. Additionally, it is an ethno-medicinal herb used in traditional Chinese medicine and Ayurvedic medicine ((Jain & Patil, 2010; Maneenoon et al., 2015; Pawar & Lalitha, 2015; Sultana et al., 2018). This plant is used by traditional healers, rural and tribal people, to treat a variety of conditions including heart diseases, bronchitis, ulcers, ringworm, itching, appetizers, sleeplessness, liver disease and leprosy (Jain & Patil, 2010; Maneenoon et al., 2015; Pawar & Lalitha, 2015; Sultana et al., 2018). In folklore preparation, the leaves have antirheumatic activities, and the leaf essence is used as a laxative (Pawar & Lalitha, 2015). In addition to having hepatoprotective, anti-helminthic, and anti-inflammatory properties, it is helpful in treating skin diseases such ringworm, eczema, scabies, rheumatism, and asthma. Its therapeutic properties are probably caused by a variety of chemical compounds and elements. (Choudhary *et al.,* 2011; Mate *et al*., 2013; Vijayalakshmi *et al*., 2015). Because *Senna tora* (L.) Roxb. contains high content of different phytochemicals, such as tannins, saponins, reducing sugar, gum, steroids and alkaloids, different parts of the plant have been shown to exhibit antioxidant, antimicrobial, anti-inflammatory and analgesic activities both *in vitro* and *in vivo* (Murshid et al., 2007).

Base on our literature search no previous review on the bioactive phytochemicals in *Senna tora* (L.) Roxb. that have reported the biological activity against oxidants, inflammation, and microbial infection, as well as the food value of the plant in a single write-up. Given this, the present article focused on the previous literature related to phytochemicals of the extract and *in vitro* antioxidant, anti-inflammatory and antimicrobial activities and food value of *Senna tora* (L.) Roxb. This will add to the literature on the plant's food and medicinal properties and provide background information for researchers who wish to carry out more advanced research on the pharmacological aspects as well as the use of the plant as functional food.

Botanical Description of *Senna tora* (L.) Roxb.

Senna tora is a small foetid, herb or undershrub weed species (Figure 1), growing in tropical and subtropical regions. It is a native of southeastern Asia and grows well in Nigeria, Malaysia, Japan, Burma, Bangladesh, India, *etc*. This species has also been referred to as a destructive weed throughout the country (Kabila *et al*., 2017). The glabrous stem of the spreading plant body has branches on it. The leaves are lanceolate, membranous, linear, or long stipulate. Three pairs of obovate, approximately equal leaflets with pubescent, glabrous surfaces over the whole margin are present. The yellow colored gland is located between the lowermost pair of the leaflets. The inflorescence is an axillary raceme with bright yellow flowers, long-stalked in pairs with a short peduncle, linear bracts and acute pubescent. Ten stamens with three staminodes and seven antheriferous (three huge anthers with a beak at the apex and four with a rounded apex) are present in the five (bright yellow), subequal, oblong, and truncate top petals (Ingle *et al*., 2012; Dubey & Sawant, 2015).

Figure 1: a) Whole Plant, b) Leaves, c) Seeds of *Senna tora* (Source: Kabila et al., 2022)

Bioactive Compounds in *Senna tora* (L.) Roxb. Leaves

Phytochemicals

Plants produce secondary metabolites, which they use to protect themselves from potential threats and environmental hazards. Since the dawn of human evolution, these metabolites and their derivatives have been useful therapeutic agents and are important in the treatment of a wide range of diseases (Erb and Kliebenstein,

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2020). Previous studies on *Senna tora* have revealed the presence of numerous phytochemical compounds from different extracts.

The presence of phenols, flavonoids, tannins, terpenoids, saponins, steroids, cardiac glycosides, alkaloids and reducing sugars were revealed in the ethyl acetate extract of *Senna tora* (L.) Roxb. leaves (Rahman *et al.,* 2023). In another study, using aqueous, ethanol, and hexane extracts, the whole plant, leaves, and seeds of *Senna tora* were subjected to phytochemical screening. In comparison to other extracts, the ethanol extracts of the whole plant, the seeds, and the aqueous extract of the seeds had the highest concentration of phytoconstituents. Carbohydrates were present in all the extracts.

Similarly, cardiac glycosides were also present in all the extracts except whole plant hexane extract. All the extracts, with the exception of hexane contain alkaloids, anthraquinones, coumarins, diterpenoids, flavonoids, phenolics, quinones, reducing sugar, starch and tannins (Kabila et al., 2022).

Alkaloids, phenols, saponins, carbohydrates, glycosides, and protein were found in aqueous, ethyl acetate, and hexane extracts of *Senna tora* leaves and seeds, according to screening results for phytoconstituents (Sabyasachi *et al.,* 2016). Alkaloids, triterpenoids, steroids, and tannins were found in the aerial portions of *S. tora*, according to research done by Rao and Chattrerjee (2016). Similarly, Asba and Meeta (2017) investigated various phytoconstituents in the roots, leaves, stem, flowers, and pods of *C. tora* using six different solvents; in comparison to other solvent extracts, most of the phytochemicals were found in the aqueous and methanol extracts. The presence of alkaloids, flavonoids, saponins, tannins, phenols, steroids in ethanol, aqueous and methanol extracts of the leaves was reported by Suradkar *et al*. (2017) and Sahu *et al.* (2017). Phytochemical screening of the seed extract of *Cassia tora* revealed the presence of carbohydrates, glycosides, saponins and triterpenes in petroleum ether, ethanol and aqueous extracts (Roopashree *et al*., 2008).

Mazumder et al., (2005) reported the presence of alkaloids and tannins in methanol extract, steroid in petroleum ether, and chloroform extracts from the leaves of *C. tora* (Mazumder *et al*., 2005**)**. The phytoconstituents of *Cassia tora* stem bark were investigated by Das et al., (2011) in five different solvents. The results showed that methanol extract contained the maximum phytochemicals, such as alkaloids, flavonoids, tannins, protein, steroids, and glycosides, followed by diethyl ether and ethyl acetate. *Cassia tora* extracts in ethanol, methanol, and ethyl acetate contain proteins, carbohydrates, steroids, terpenoids, and cardiac glycosides whereas tannins and phlobatannins were only present in methanol and ethanol extracts (Veerachari & Bopaiah, 2012**)**. John et al., (2012) also observed that the *C. tora* leaf extracts in methanol and ethyl acetate contained tannins, anthraquinones, flavonoids, glycosides, and coumarins; however, the methanol extract only revealed steroids, cardiac glycosides, amino acids, and saponins. Alkaloids, anthraquinones, flavonoids, phenolics, and proteins were present in the methanol and aqueous extracts of *C. tora* leaves (Khan et al., 2016). Ethyl acetate and methanol extracts of leaves indicated all the phytoconstituents under study among the leaves, bark, seeds, and pods (containing seeds), however, hexane extract revealed the presence of only steroids (Khatak *et al*., 2014).

A comparative analysis of the seasonal variation of phenol, tannin and ascorbic acid contents was investigated from leaves, stem, root and seeds of *Senna tora.* The phenol contents revealed that the amount was higher in the leaves (5.740 to 6.408 mg/g dry weight) than in the stem (3.768 to 4.419 mg/g dry weight), root (1.284 to 1.828 mg/g dry weight), and seeds (3.873 mg/g dry weight). In terms of tannin concentrations, the amount was higher in the leaves (0.356 to 0.410 mg/g dry weight) than in the stem (0.300 to 0.356 mg/g dry weight), root (0.112 to 0.156 mg/g dry weight), and seeds (2.940 mg/g dry weight). In addition, ascorbic acid concentrations revealed higher amount in the leaves (range 3.011 to 3.620 mg/g dry weight) than in the stem (range 1.988 to 2.612 mg/g dry wt.), root (range 0.970 to 1.109 mg/g dry weight), and seeds (2.067 mg/g dry weight) (Gaykhe et al., 2018).

Phytochemicals are nutritional or non-nutritional bioactive plant compounds found in fruits, vegetables, cereals, and other plant foods. They may have health advantages in addition to basic nutrition, such as lowering the risk of major chronic diseases (Kumar et al., 2023). Phytochemicals, after extraction from various sources, find profound application in the development of functional foods and nutraceuticals.

Antioxidant Activity

ROS can be produced exogenously or endogenously in living organisms. In order to combat ROS, the external supply of antioxidants either scavenges ROS or stimulates the body's own (enzymatic and nonenzymatic) antioxidative systems. Natural antioxidants produced from medicinal and dietary plants are commonly used as therapeutic agents.

Rahman *et al.,* (2023) concluded that ethyl acetate extract of *Senna tora* (L.) Roxb. leaves scavenges H_2O_2 in a dose-related manner. The DPPH and H_2O_2 scavenging capacity of ethyl acetate extract of *Senna tora* (L.) Roxb. leaves may arise from the phenolics, terpenoids, vitamin C, vitamin E, and carotene (Rahman *et al.*, 2023). Nkwocha et al., (2023) reported that phytochemical analysis of the methanolic fraction of *Cassia tora* leaves indicated the presence of saponins (71,760±943.2μg/ml), terpenoids (47,466.70±46.2μg/ml), tannins (21,253.30±46.2μg/ml), flavonoids (14,682.70±40.3μg/ml), phenols (30,986.70±46.2μg/ml), steroids (13,557.30±24.4μg/ml), alkaloids (9770.67±9.2μg/ml), glycosides (5434.67±139.8μg/ml). The methanolic fraction of *Cassia tora* leaves was found to have antioxidant properties. The higher the fraction's scavenging power, the lower the standard (ascorbic acid) concentration. In comparison to the standard (ascorbic acid), the fraction had the maximum antioxidant capacity at 6.86mg/ml. The fraction's total antioxidant power varied from 1.78 mg/ml to 16 mg/ml.

Anti-inflammatory Activity

During inflammation, leukocytes discharge lysosomal enzymes, and proteases are part of their protective roles, causing more damage to the tissue (Erfle et al., 1997). Preventing hemolysis of the RBC membrane can provide insight into anti-inflammation because the RBC membrane and the lysosome membrane are identical. The firmness of such a plasma membrane can prevent or postpone cytolysis, preventing the liberation of cytosolic elements and, consequently, preventing tissue injury and the inflammatory reaction. Protein denaturation is one additional reason for inflammation (Oyedapo & Famurewa, 1995). An aid that can inhibit protein damage could be helpful in the treatment of inflammatory disorders. According to Rahman et al. (2023), ethyl acetate extract of *Senna tora* (L.) Roxb. leaves inhibited BSA protein denaturation and RBC lysis, demonstrating concentration-dependent anti-inflammatory action. The findings show that the ethyl acetate extract of *Senna tora* (L.) Roxb. leaves contains esters, phenolics, terpenes, hydrocarbons, ketones, and aldehydes, which may be responsible for this anti-inflammatory activity.

Antimicrobial Activity

The bacterial strains are contagious and have the ability to cause illness. For example, a newborn with sepsis was found to have B. infantis, and bacteremia and pneumonia are promoted by Exiguobacterium sp (Chen et al., 2017; Ko et al., 2006). According to Guo et al., (2020), *S. aureus* is one of the most common pathogens in humans, aggravating endocarditis, bacteremia, and infections of the soft tissues and respiratory tract. According to Davis et al., (2020), some *Streptococcus* sp. contributes to the pathogenesis of upper respiratory infections, while virulent *E. coli* hastens the development of urinary tract infections and gastroenteritis (Garretto et al., 2020). The enteric pathogen *V. cholerae* produces acute secretory diarrhea by releasing the cholera toxin (Satitsri et al., 2016). *S. typhi* is an MDR-resistant bacterial pathogen that usually causes typhoid and paratyphoid, and it has rapidly gained resistance to previously efficacious drugs, such as ciprofloxacin (Mannan et al., 2014). By impairing the immune systems of afflicted individuals, *P. aeruginosa* can cause serious, potentially fatal infections (Moradali et al., 2017). *H. influenzae* is the main bacterial agent that spreads diseases in the respiratory and sensory systems of the body (Wajima et al., 2016). The antibiotic activity of ethyl acetate extract of *Senna tora* (L.) Roxb. leaves was assessed against these bacteria (Rahman *et al.,* 2023). The presence of bioactive compounds such as phenolics, esters, terpenes, hydrocarbons, aldehydes, and ketones were reported to account for this antibacterial action (Rahman *et al.,* 2023).

Mohhite et al., (2018) evaluated the *in vitro* effect of aqueous leaves extract of *Cassia tora* on *Escherichia coli*, *Staphylococcus aureus*, *Bacillus* spp., *Pseudomonas aeroginosa*. The results demonstrated that *Cassia tora* leaves had antibacterial activity. In a different investigation conducted by Das et al. (2010), it was discovered that the leaves of *Cassia tora* L. exhibited antibacterial activity (0-5000 μg/ml) against 38, 58, and 29 different bacterial strains, respectively, out of 120 total bacterial strains. Additionally, methanol extracts demonstrated antifungal activity (0-64 mg/ml) against three out of four strains. Three *Escherichia coli* bacteria, four *Staphylococcus aureus* strains, and five *Shigella dysenteriae* strains have demonstrated sensitivity to the methanol extracts up to a 2000 μg/ml concentration when treated in vitro. For dermatophytes, the minimum inhibitory concentration (MIC) values vary from 2 to 64 mg/ml. Minimal Bactericidal Concentration (MBC) value lies in the range of 2000-2500 μg/ml against *Escherichia coli* ATCC25938 and *Shigella dysenteriae*.

Bhalodia et al., (2011) reported the antibacterial activity of leaf extracts on a range of human diseases. Mukherjee et al. (1996) observed that leaf extract had antifungal activity.

Food Values

Leaves and seeds are edible. While the roasted seeds are used as a substitute coffee (Hanh et al., 2021), young leaves can be cooked as a vegetable. In Sri Lanka the flowers are added to food. It is made into tea; this tea has been referred to as coffee-tea, due to the taste and aroma of coffee (Das et al., 2012**)**. Moreover, the seed gums are used as thickener in foods (Cunningham and Walsh, 2001). Santhal tribes of Odisha state, in India collects the leaves and dry them and cook with pulses (Mety *et al.*, 2024).

Conclusion and Further Research/Future Studies

The review concluded that *Senna tora* (L.) Roxb. contain antioxidant, anti-inflammatory, and antimicrobial activities due to the presence of some biologically active phytochemicals, viz., phenolics, flavonoids, terpenoids, tannins, vitamin C, vitamin E, saponins, steroids, cardiac glycosides, alkaloids. Moreover, the young leaves can be cooked as a vegetable while the roasted seeds are used as a substitute coffee. Thus, the present review has explained the potentiality of *Senna tora* in the pharmaceutical sector and in the development of functional foods.

This species can provide raw materials for the preparation of new or alternate medicine and functional foods. Research gaps in information concerning isolation of these phytochemical compounds with fascinating *in vitro* and *in vivo* pharmacological properties and to assess their safety and bioavailability in *in vivo* animal models to aid in developing drugs against oxidants, inflammation, and microbial infection is warranted.

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