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Review Article

SENNA ALATA: PHYTOCHEMICAL COMPONENTS, CHARACTERIZATION AND MEDICINAL BENEFITS

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ABSTRACT
The growing rate of the activities of microbes increases every day. Virtually everything that surrounds man are contaminated and polluted with these microbes. These contaminations have led to some infectious and contagious diseases some of which are curable and others deadly. The advancement in Science and Technology have helped reduced this problems to certain level. In doing this, different researches have been carried out on medicinal plants in order to combat these problems. In this research, phenolic compounds were found broadly distributed in the plant kingdom and are the most abundant secondary metabolites of plants. They are reactive metabolites in a wide range of plant-derived foods and mainly divided in four groups: phenolic acids, flavonoids, stilbenes and tannins. They work as terminators of free radicals and chelators of metal ions that are capable of catalyzing lipid oxidation. Therefore, this review examines the functional properties of phenolics and their health benefits, phytochemical constituents and advanced characterization methods for the analysis of phenolic compounds.

Keywords: *Chelators, Free Radicals, Lipid Oxidation, Microbes, Phenolics, Phenolic Compounds, Secondary Metabolites*

INTRODUCTION

S. alata (previously named *Cassia alata*) is a medicinal plant of Leguminosae Family of Fabaceae Family. It has many common names such as Candle bush, Acapulo, Ringworm bush and Calabra bush. In the Southwest of Nigeria; *S. alata* is called 'Ewe Asunwon Oyinbo'. It is found in Ghana and Brazil, but it is now widely distributed in the United States of America and all over Africa, including Nigeria (Kumar, 1984). It is a shrub with usually an average height of between 1 and 5 metres and has horizontally spread branches. Its leaves are par pinnate of between 30 to 60 cm long and consisting of 8 to 20 pairs of leaflets. Each leaflet is oblong or elliptic oblong and rounded at both ends. The petioles are robust (2 to 3 mm long). Its flowers are dense in auxiliary racemes, about 20 to 50 cm long and 3 to 4 cm broad. The bracts are caduceus, 2 to 3 by 1 to 2 cm in dimension. The plant fruits are a thick, flattened with wings and glabrous pods. The wings are 5 mm broad while there are about 50, flattened, more or less quadrangular black seeds (7 to 10 by 5 to 8 mm in dimension). They grow well in full sun in a wide range of soils that retain moisture adequately. The plant grows often along ditches between rice-fields. The plants are usually propagated by seeds and distributed all over the country up to 1,500 m above sea level; they are most often cultivated for medicinal purposes (Farnsworth and Bunyapraphatsara, 1992).

Distribution and Geographical Source of Senna Alata

It is an annual or biennial shrub and grows aggressively in areas where there is high water table. It prefers open areas and sunlight. Often forms thickets and grown as ornamental. *S. alata* (*Cassia alata*) Linn. (Fabaceae) is an ornamental flowering plant (Khare, 2007) native to the Amazon Rainforest. Due to its beauty, it has cultivated in tropical Africa, tropical Asia, Australia, Mexico, the Caribbean islands, Melanesia, Polynesia, Hawaii and widely distributed throughout the different parts of India like, Chattisgarh, Maharashtra, West Bengal, Andhra Pradesh etc (Ross, 1999). It grows well in forested areas of West Africa. In Indonesia, Philippines and Thailand (Palanichamy and Nagarajan, 1990), this plant can be found all over the countries, sometimes cultivated for medicinal purposes (Baansiddhi and Pechaaply,

1988). After 3 months of planting, leaves are ready for harvest, but the best period for the best quality is about 6-7 months after planting. South America found widely in tropical region, up to 1500 m, on waste places often along ditches (Damodaran, 1988).

Phytochemical Components in Senna Alata

The medicinal values of the plants depend on the presence of certain chemical substances (secondary metabolites) that are involved in production of different kinds of effects on human body. Secondary metabolites in plants involved in production of medicines are alkaloids, tannins, flavonoids, terpenes and phenolic compounds. These substances have role in plant defense mechanisms by protecting them against predation by insects, microorganisms and herbivores. Some compounds are responsible to give plants their specific odours and others are responsible for imparting different colours to plants. Some of these metabolites are involved in giving characteristic flavours to plants and others are used for the seasoning of food and obtain some active compounds of medicinal importance (Cowan, 1999). Some classes of phytochemicals are given in detail below.

Phenolics and Polyphenols

Plants are able to make a wide range of aromatic compounds; more common among them are phenols or their derivatives having oxygen substitution. Phenolic compounds are plant secondary metabolites that constitute one of the most common and widespread groups of substances in plants. The term "phenolics" or "polyphenols" are defined as substances that possess an aromatic ring having one or more hydroxyl substituent and functional derivatives such as esters, methyl ethers, glycosides, etc. The terms phenolics and polyphenols refer to all secondary natural metabolites arising biogenetically from the shikimate-phenylpropanoids-flavonoids pathways, producing monomeric and polymeric phenols and polyphenols. Phenolics with only few hydroxyl groups are soluble in ether, chloroform, ethyl acetate, methanol, and ethanol. Each class of phenolic compounds has distinctive absorption characteristics (Mabry *et al.,* 1970; Harbone, 1984). Plants need phenolic compounds for pigmentation, growth, reproduction, resistance to pathogens and for many other functions. These compounds form one of the main classes of secondary metabolites and several compounds have been identified with a large range of structures: monomeric, dimeric and polymeric phenolics (Kliebenstein, 2004).

Phenolics are uncommon in bacteria, fungi and algae and the classes of phenols recorded are few: flavonoids are almost completely absent. Bryophytes are regular producers of polyphenols including flavonoids, but it is in the vascular plants that the full range of polyphenols is found (Bell, 1980; Harbone, 1980). They may be divided into two classes: namely preformed phenolics that are synthesized during the normal development of plant tissues and induced phenolics that are synthesized by plants in response to physical injury, infection or when stressed by suitable elicitors such as heavy metal-salts, UV-irradiation, temperature, etc. (phytoalexins). Induced phenolics may also be constitutively synthesized but, additionally, their synthesis is often enhanced under biotic or abiotic stress (Dixon *et al.,* 2002; Winkel-Shirley, 2002).

In general, however, preformed antifungal phenolics are commonly sequestered in conjugated form, usually with glycosidic attachments, in vacuoles or organelles in healthy plants (Beckham, 2000; Lattanzio *et al.,* 2001; Morrissey *et al.,* 1999). Biotrophs may avoid the release of preformed antibiotics by minimizing the damage to the host, whereas necrotrophs are likely to cause a substantial release of these compounds.

Tannins

Plant phenolic polymer with defensive properties is tannin. There are two categories of tannins, condensed and hydrolysable. Condensed tannins are compounds formed by the linkage of flavonoid units. They are frequent constituents of woody plants. Condensed tannins can often be hydrolyzed to anthocyanidins by treatment with strong acids and so are called "proanthochocyanidins" (Figure 1). Hydrolyzable tannins are heterogeneous polymers containing phenolic acids, especially gallic acid and simple sugars. They may be hydrolyzed more easily with dilute acid. Tannins are general toxins that significantly reduce the growth and survivorship of many herbivores when added to their diets. In addition, protect the plants from prey, that is, act as feeding repellents to a great diversity of animals. In

humans, tannins constitutes to certain properties, such as a sharp, unpleasant, astringent sensation in the mouth due to their binding of salivary proteins (Oates *et al.*, 1980).

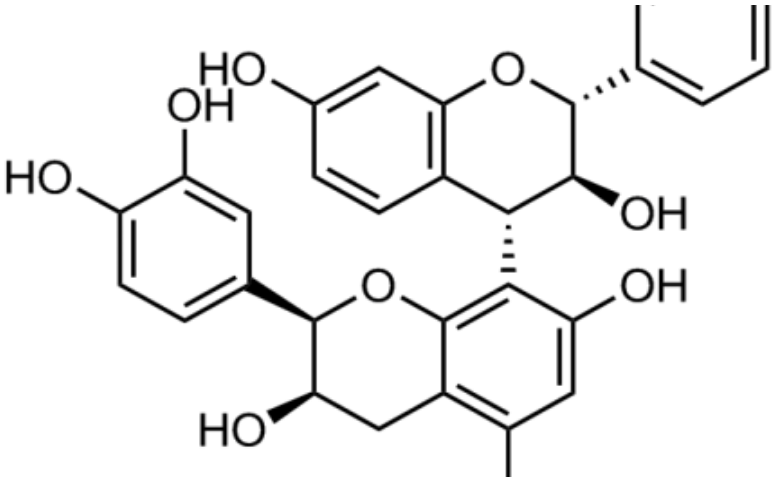


Figure 1: Proanthocyanidins Structure

The defensive properties of tannins have been attributed to their ability to bind proteins. The tannins can activate the herbivore's digestive enzymes by binding proteins and so creating complex aggregates (Clausen *et al.*, 1992). It also acts as antimicrobial agents. For example, the nonliving heartwood of many trees contains high concentrations of tannins that help prevent fungal and bacterial decay (Schultz *et al.*, 1992).

Flavonoids

Flavonoids are the largest group of polyphenolic compounds. They are widely distributed throughout the plant kingdom. Flavonoids are characterized as containing two or more aromatic rings, each bearing one or more phenolic hydroxyl groups, and connected by a carbon bridge (Beecher *et al.*, 2003). One aromatic ring (A ring) is connected to the second aromatic ring (B ring) by a carbon bridge which consists of three carbon atoms. To date, more than 6,000 different flavonoids have been described and the number continues to increase (Harborne *et al.*, 2000). When the three carbon chain is connected to a hydroxyl group, they form a cyclic structure (C ring), as a 6-membered ring. Most flavonoids bear this type of phenylbenzopyrane structure (Figure 2). They have further been subdivided into subclasses, based on the position of the B ring relative to the C ring, as well as the functional groups (ketones, hydroxyls) and presence of a double bond in the C ring. These subclasses are termed flavones, isoflavones and isoflavonones, flavanones, flavanols, anthocyanidins, chalcones and dihydrochalcones (Beecher *et al.*, 2003). Flavonoids which are widespread in the plant kingdom, serve specific functions in antimicrobial activities, flower pigmentation, UV-protection, plant defense against pathogens and legume nodulations (Dixon, 1986).

The flavonols are the most widespread of the flavonoids in plant food. They vary in color from white to yellow and are closely related in structure to the flavones. Examples of flavonols are quercetin, kaempferol, and Myricetin while the methylated derivative isorhamnetin is also quite common. Of the various flavonols found in the diet, quercetin is the most important (Crozier *et al.*, 1997). Flavonols that accumulate in plant tissues are almost always in the form of glycosylated conjugates. They are found in flowers and leaves of green plants; they generally absorb light at shorter wavelengths than anthocyanins and are not visible to human eyes (Hertog *et al.*, 1992).

Flavones are structurally similar to flavonols and differ only in the absence of hydroxylation at the 3-position on the C-ring. Flavones are present in the diet as apigenin and luteolin (Wang *et al.*, 2003). Flavones are not restricted to flowers alone, but also present in the leaves of all green plants. It has been suggested that two classes of flavonoids protect cells from excessive UV radiation, because they absorb

light strongly in the UV region while letting the visible wavelengths pass through uninterrupted (Cadwell *et al.,* 1983). Recent observations reveal that when flavones are methoxylated, metabolic stability and membrane transport in the intestine or liver dramatically increases, thus improving oral bioavailability (Walle, 2007).

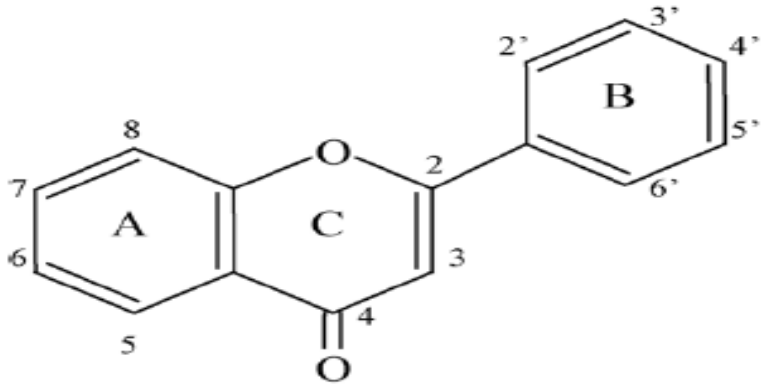


Figure 2: The Basic Structure of Flavonoids

Flavan-3-ols are structurally the most complex subclass of flavonoids ranging from the simple monomers (+) - catechin and its isomer epicatechin to the oligomeric and polymeric proanthocyanidins, which are also known as, condensed tannins (Crozier *et al.,* 2000). They are found in fruits (Porter, 2008) and can undergo esterification with gallic acid to form catechin gallates, and hydroxylation reactions to form gallocatechins. Flavan-3-ols represent the most common flavonoid consumed in America and, most probably, the Western diet and are regarded as functional ingredients in various beverages, whole and processed foods, herbal remedies, and supplements. Their presence in food affects quality parameters such as astringency, bitterness, sourness, sweetness, salivary viscosity, aroma, and color formation (Aron *et al.,* 2007).

Anthocyanins are water-soluble plant pigments and are particularly evident in fruit and flower's tissue where they are responsible for a diverse range of red, blue, and purple colors. They occur primarily as glycosides of their respective aglycone anthocyanidin-chromophores, with the sugar moiety typically attached at the 3-position on the C-ring or the 5-position on the A-ring (Prior *et al.,* 2006). Without their sugars, anthocyanins are called "anthocyanidins". They are involved in the protection of plants against excessive light by shading leaf mesophyll cells, in attracting pollinating insects and responsible for most of the red, pink, purple and blue colours observed in plant parts. There are about 17 anthocyanidins found in nature, but only six - cyanidin, delphinidin, petunidin, peonidin, pelargonidin, and malvidin - are ubiquitously distributed and of dietary important. The variation of anthocyanins are due to: the number and position of hydroxyl and methoxy groups on the basic anthocyanidin skeleton; the presence of chelating metals such as iron and aluminium; and the presence of flavones or flavonol copigments and the pH of the cell vacuole in which these compounds are stored (Taiz *et al.,* 1991).

Isoflavones are characterized by having the B-ring attached at C_3 rather than the C_2 position. They have a very limited distribution in the plant kingdom with substantial quantities being found only in leguminous species (Dixon *et al.,* 1986). They also undergo various modifications, such as methylation, hydroxylation, or polymerization, and these modifications lead to simple isoflavonoids, such as isoflavanones, isoflavans and isoflavanols, as well as more complex structures including rotenoids and pterocarpans (Dewick, 1993).

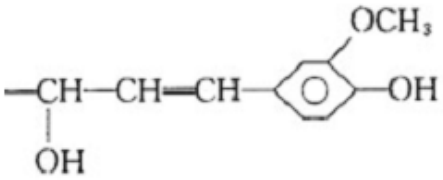
Isoflavonoids are antimicrobial compounds called "phytoalexins". Phytoalexin accumulation in high concentrations has great importance of the resistance mechanism against pathogenic microbes (Ebel, 2004). Naturally occurring Flavonoids have been recognized for their antimicrobial activity. This makes

them significantly important in the field of medical microbiology. Many research groups have isolated and identified the structures of Flavonoids possessing antifungal, antiviral and antibacterial activity (Prior *et al.*, 2006). These properties of Flavonoids enable them to be used extensively in the area of nutrition, food safety, and health. The antiviral effect of Flavonoids was shown in a study carried out by Wang *et al.*, (1998). All the Flavonoids, with some exceptions, are used in the therapy for viral disease and are effective against a number of viral infections. Naturally occurring Flavonoids such as Quercetin, Naringin, Hesperetin, and Catechin possess a variable spectrum of antiviral activity (Tej *et al.*, 2005).

Lignin

Lignin, which is the most abundant organic substance in plants, is generally formed from three different phenylpropane alcohols, coniferyl, coumaryl and sinapyl alcohol synthesized from phenylalanine via various cinnamic acid derivatives (Figure 3) (Gottlieb, 1992).

A.



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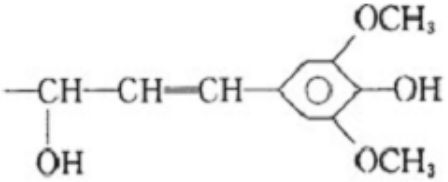

C.

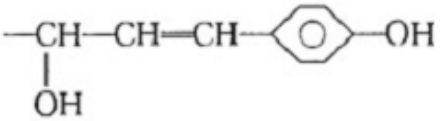

Figure 3: Basic Structural Unit of Lignin (A = Conifergl Alcohol; B = Coumargl Alcohol; C = Sinapyl Alcohol)

Phytochemical Extraction and Investigation

Plant cells and organs produce a large number of chemical substances or metabolites. In attempt to investigate the secondary metabolites, certain chemical methods are required. These include extraction of plant materials and separation of compound of interest. One of the commonest methods of extraction is solvent extraction using different solvents of different polarities. The analytical methods involved in the extraction of secondary metabolites or compounds from plant material include,

(i) Pre-Extraction: In pre-extraction, plant materials are rinsed to remove the impurities, air dried under certain conditions, pulverized and stored for further analysis.

(ii) Extraction: In extraction plant material is extracted with solvent to get crude extract. There are different techniques used for solvent extraction are maceration, percolation and soxhlet extraction.

(iii) Fractionation: In fractionation, the crude extract is divided into different fraction a cleanup methods, commonly column chromatography using solvents of different polarities. After obtaining the crude extract fractionation is almost always the next step. Crude extracts are not suitable for sophisticated

chromatographic or spectroscopic techniques because of wide range of polarities or extraneous substances. Therefore, it is better to fractionate crude extract into different fractions. Each fraction contains the same compounds in the same polar region (Evans, 2002).

(iv) Compounds Isolation and Structure Elucidation: In the attempt to isolate and elucidate the structure of the plant secondary metabolites, different chromatographic and spectroscopic techniques are generally used for the identification of compounds of interest.

Advanced Characterization Methods for the Analysis of Phenolic Compounds

The biological activity of plants is basically due to the presence of certain structural feature of a compound or its metabolite. One of these features is the effect of structural features like conjugated double bonds; this dictates UV absorption properties of some flavonoids or phenolic compounds. Alternatively, a certain activity may depend on the stereochemistry of the compound since target enzymes and biological systems in general are stereo-specific. Therefore, it is inevitable to characterize the compounds present in plant materials.

Phenolic compounds are extracted and purified or clean up from the plant material before structural characterization of the compounds. First, the metabolic activity of the plant is halted by flash freezing and lyophilization or by extraction of the plant materials using solvent of high polarity such as methanol, ethanol and acetone. The samples were pulverized and subjected to pre-treatment before extraction in order to improve the extraction yield. The crude extract may be purified using cleanup methods such as adsorption, partition, gel permeation, ion exchange etc and also, column chromatographic methods such as gel filtration over Sephadex LH-20 and reversed-phase (RP) chromatography (Waterman and Mole, 1994).

There are many physicochemical methods used for the identification of a specific compound. This is usually achieved by a combination of several physicochemical methods, such as ultraviolet spectroscopy (UV), gas chromatography-mass spectrometry (GC-MS), circular-dichroism spectroscopy (CD), optical rotation, nuclear magnetic resonance spectroscopy (NMR), mass spectrometry (MS), and X-ray crystallography. If the compound of interest is already known, it can be identified with less measurement by comparing its characteristic features with literature values or the data of standard compounds.

The quantification of active compounds in medicinal plants have become very significant, it has been shown that in-vitro screening methods could provide the needed preliminary observations necessary to select crude plant extracts with potentially useful properties for further chemical and pharmacological investigations (De Fatima *et al.*, 2006). The phenolic compound in *S. alata* varied from the leaf to the flower and this led to different approaches by the scientists to screen the plant for its therapeutic potency (Owoyale *et al.,* 2005). In recent research carried out on *S. alata* plant, it was discovered that it contain hundreds of bioactive compounds (De Fatima *et al.,* 2006). The compositions of these compounds are not the same and also, it was discovered that different bioactive compounds were present and this dictate its therapeutic functions.

Column Chromatography

Column chromatographic technique is use to purify compounds of interest from a compounds mixture by using glass tube of varying length and diameter. The stationary phase is packed in a glass column of varying diameter.

The stationary phase is solid and is mostly silica gel and alumina. Organic solvent either a single solvent (isocratic) or different solvents (gradient) are used as the mobile phase. It is a slow process and its slight modified form flash column chromatography is used in which slight air pressure is applied to accelerate the movement of solvent (Wang *et al.*, 1998).

Normal Phase column chromatography is technique in which normal phase silica is used as stationary phase and in eluting, the mobile phase is applied in raising order of polarity that is starting from the least polar one and ending at the most polar one.

The technique in which reverse phase silica is used as stationary phase and mobile phase is also applied in the reverse order that is starting from the most polar solvent and ending at the least polar is known as reverse phase column chromatography.

High Performance Liquid Chromatography (HPLC)

In recent times, there are some new and improved forms of column chromatography; an example of this is high performance liquid chromatography. It is commonly used in the quantification of phenolic compounds. In this case solvent is forced through the column under high pressures of up to 400 atmospheres. High pressure accelerates the whole process and it takes much less time as compared to column chromatography. The other major advantage over column chromatography is the detection methods involved in HPLC that are highly sensitive and automated.

Thin Layer Chromatography (TLC)

Thin Layer Chromatographic techniques are commonly used to separate and investigate mixtures or fractions of plant compounds. In thin layer chromatography (TLC) a sheet (glass or plastic) is used after coating it with a thin layer of adsorbent material (such as silica gel and alumina or cellulose) called stationary phase. When the sample is applied on the plate, a solvent or solvent mixture (mobile phase) draws up the components of sample on the plate by capillary action. Different components of mixture travel on the TLC plate with different rate that depend on polarity of solvents and compounds and their relation with stationary phase with respect to polarity. The retardation factors give the presence of the plant metabolites or compounds of interest.

Liquid Chromatography-Mass Spectrometry (LC-MS)

It is an analytical technique in which the separation potential of liquid chromatography is coupled with a mass spectrometer. The technique is used for characterization of plant samples where high selectivity and sensitivity is demanded. It has an advantage over GC-MS mainly because it can be used for separating plant materials that contains compounds that are highly polar and less volatile.

Gas Chromatography-Mass Spectrometry (GC-MS)

Gas chromatography-mass spectrometry (GC-MS) is an analytical chemistry technique in which gas-liquid chromatography and mass spectrometry are coupled to get knowledge about different substances within a test sample. GC-MS can be helpful for discovery and detection of drugs, investigating fire, analyzing environment and changes in environment, for investigating explosives and for the identification of unknown samples by comparing them with reference standards present in GCMS catalogue. The GC-MS is made up of two major components: the gas chromatograph and the mass spectrometer.

In gas chromatograph, a capillary column is used through which different molecules are passed. Chemical properties of individual molecules are different. So, different components in a mixture, will be separated as the sample travels through the length of the column. Depending on the polarity and other chemical properties of molecules they differ in their elution time through capillary column. So, different peaks appeared for different compounds with different retention time. The mass spectrometer breaks down individual molecules into different fragments. These fragments are then detected on the basis of mass to charge ratio. By using both parts of BC-MS finer degree of substance identification can be achieved. That cannot be achieved by using either of these units separately.

Fourier Transform Infrared (FTIR) Spectroscopy

It is used to identify chemical bonds in a compound by production of an infrared absorption spectrum. FTIR analysis produces absorption spectra which provide information about the molecular structure of a material by identifying different bonds and functional groups present in the compounds. The FTIR spectrum is comparable to the reference catalogues and in this way different bonds can be identified.

NMR Spectroscopy

"While no single form of spectroscopy is currently capable of resolving all structural problems, NMR spectroscopy is probably the technique of paramount importance" (Snyder *et al.,* 1989). This statement was made by J. Snyder and coworker back in 1989 and is still valid today. With NMR measurements, it is possible to obtain the constitution of a compound and sometimes even the configurationally and conformational structure. The NMR phenomenon is based on the ability of certain atomic nuclei to receive electromagnetic energy at a characteristic frequency supplied by radio frequency pulses in a static magnetic field, and thereby attain a higher resonance state. The exact resonance frequency of each nucleus is dependent on the chemical environment of the nucleus. The difference in the resonance

frequency of the nucleus and a standard (usually tetramethylsilane, TMS) is called chemical shift (δ/ppm). The nucleus will resonate at two slightly different frequencies, i.e. the resonance line will split, if the nuclear spin is coupled to a magnetically non-equivalent nucleus via bonding electrons. This spin coupling is characterized by a coupling constant (J/Hz).

Medicinal Uses of Senna Alata

The plant is very important in many areas of life. The applications are so numerous. The applications include for medicinal purposes, antimicrobial activities, antioxidant activities, its nutritional values and many others. Different parts and constituents of the plant are reported to exhibit several therapeutic properties, such as antibacterial, antifungal, antimicrobial and analgesic. The leaves of this plant are used in the treatment of ringworm. The plant is traditionally acclaimed to be effective in treating skin infections in man (Igoli *et al.,* 2005) and animals. It is also reported that the leaf is useful for the treatment of hemorrhoids, constipation, inguinal hernia, intestinal parasitosis, syphilis and diabetes. The seed is used as antihelminthic, the roots are used against uterus disorder, and the crushed leaves are used for skin infections (Herman *et al.,* 1978). All the parts of this plant have been reported to have one or more medicinal action especially antimicrobial activities (Makinde *et al.,* 2007). In many parts of the world, *S. alata* leaves, fruits and flowers have long been traditionally used as laxatives and antifungal agents (Farnsworth and Bunyapraphatsara, 1992).

The possible health benefits of dietary phenolics depend on their absorption and metabolism, which in turn are determined by their structure including their conjugation with other phenolics, degree of glycosilation/acylation, molecular size and solubility.

Antibacterial Activities of *Senna Alata*

Oleanolic acid isolated from *S. alata* leaf extract inhibits the growth of *Escherichia coli, Salmonella typhi*, *Proteushat mirabilis* and *Klebsiella pneumonia* (Senthilkumar and Reulta, 2011). The petals of the flower contain high amount of flavonoids, this is known to inhibit the growth of *Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis*, *Pseudomonas aeruginosa* and *Proteus vulgaris* (Taylor, 2005). Flower of *S. alata* is known to contain high amount of phenolic compounds which are active component of the plant that contribute to the antibacterial activities of the plant (Senthilkumar and Reulta, 2011). 1, 3, 8, trihydroxy-6-methyl-anthraquinone was isolated from *S. alata* methanolic leaf extract. This compound is the bioactive molecule present in methanolic extract was effective against the oral microflora (Gaikwad, 2014). Also, there are some compounds present in the plant such as 3,4-dihydroxycinnamic acid, cannabinoid dronabinol alkaloid, Kaempferol-O-diglucoside, quercetin-O-glucoside, kaempferol-O-glucoside, kaempferol, rhein and danthron are known to inhibit the growth of both gram positive and gram negative bacteria.

Antifungal Activities of Senna alata

Leaf extract of *S. alata* have shown high potency bacteria (both gram positive and gram negative) and fungi. They are found to be effective against *Trichophyton mentagrophytes* and *C. albicans* (Indira and Laskshimi, 2013). Due to the antifungal activities of *S. alata*, different researches have been carried out to the potency of the plant. Methanolic leaf extract showed high activity against Mucor, Rhizopus and *Aspergillus niger* than ethanolic and petroleum ether extracts (Palanichamy and Nagarajan, 1990). Flower extract of *S. alata* is an important antifungal agent, for inhibiton of growth of aflatoxin producing fungi (*Aspergillus flavus* and *Aspergillus parasiticus*), plant pathogenic fungi (*Fusarium oxysporum*) and human pathogenic fungi (*Candida albicans*) (Adjanohoun *et al.,* 1991). The root and leaf extracts inhibited the growth of *Aspergillus flavus*, *Aspergillus niger*, and *Candida albicans* (Esakkirajan, 2014). Cannabinoid dronabinol alkaloid isolated from the seeds of *S. alata* inhibited the growth of *Aspergillus niger* and *Candida albicans* (Donatus and Fred, 2011). The chronic fungal disease, *Pityriasis versicolor* was cured without recurrence for 1 year by using aqueous extracts of fresh leaves of *S. alata* (Gaikwad, 2014).

Antioxidant Activities of Senna Alata

Antioxidants are compounds that protect the cells against the oxidative effect of reactive oxygen species, such as singlet oxygen, peroxyl radical and peroxynitrite. The impaired balance between these reactive

oxygen species and antioxidants results in a condition commonly referred to as oxidative stress. This oxidative stress may lead to cellular damage which is linked to various health deficits such as diabetes, cancer, cardiovascular disorders, neurodegenerative disorders and aging (Juvekar and Halade, 2006; Makinde *et al.*, 2007). 1-(4"-hydroxyphenyl) 2,4,6-trihydroxy-indole-3-carboxylic acid was isolated from *S. alata* ethyl acetate fraction and it exhibited a strong DPPH radical scavenging activity (El-Mahmood and Doughari, 2006).

Redox properties of phenol and flavonoids play an important role in absorbing and neutralizing free radicals. Presence of phenols, anthraquinone, flavonoids, carotenoids, Vitamin-C and Vitamin-A in the methanolic leaf extract of *C. alata* indicates strong DPPH radical scavenging activity (Souwalak *et al.*, 2004).

Wound Healing Activities of Senna Alata

Wounds are the physical injuries that result in an opening and breaking of the skin and appropriate method for healing of the wound is essential for the restoration of the disrupted anatomical continuity and disturbed functional status of the skin (Manogaran and Sulochana, 2004). The ethanol extracts of leaves of *S. alata* were investigated on excision wound model in rats. The leaf extract accelerated the wound healing potential by reducing the epithelialisation period; prevent high risk of sepsis and prolongation of inflammatory phase (Midawa, 2010). *S. alata* has been identified as a medicinal plant used in the treatment of many ailments in many parts of the World (Idu *et al.*, 2006). The sap of the leaves is a well known remedy for ringworm, scabies, and ulcers, swelling and inflammation conditions and skin parasites (Shivananda, 2006). Decoction from the leaves, flowers, barks and wood of the plant is reported to be effective in the treatment of skin.

Anti-Inflammatory Activities of Senna Alata

S. alata flowers contain flavonoids and bioflavonoids, this help in the inhibition of lipid peroxides and decreased levels of lysosomal enzymes. *S. alata* leaves possess DL-α-tocopheryl-α-D-mannopyranoside and DL-α-tocopheryl-β-D-galactopyranoside having the anti-allergic and anti-inflammatory activities (Anonymous, 1996). 5-O-methylquercetin 7-O-glucoside was isolated from *S. alata* flower exhibited anti-inflammatory activity (Manogaran and Sulochana, 2004). Kaempferol-3-O-gentiobioside, a flavonoid glycoside isolated from *S. alata* leaves showed anti-inflammatory activity (Morton and Malone, 1972).

Anti-Skin Infections Activities of Senna Alata

S. alata leaf was known for the treatment eczema, itching and skin infections in humans (Palanichamy and Nagarajan, 1990; Morah and Otumu, 1991; Ogunti and Elujoba, 1993). Applications of ointment prepared from ethanolic leaf extracts were effective in curing bovine dermatophilosis. The ointment reached the affected area directly and penetrated the epidermis of the skin, falling off of the crusts and quickly inhibited the development of *D. congolensis* (Aletor, 1993).

Conclusion

The advancement in the world has led to the production of synthetic drugs. The consistent use of these drugs have increased the development of drug resistance in human pathogens as well as the unwanted side effects of some commonly used synthethic antimicrobial agents prompted the search for natural antimicrobial agents for effectiveness and safety. The discovery of phenolic compounds in plant have tremendously reduced the side effects encountered from synthetic drugs. All the classes of phenolic compounds showed important health benefits, this is due to the important chemical characteristics or functional groups present. In view of this, the Scientist have discovered that in order for man to survive these conditions, the introduction of natural antimicrobial and antioxidant agents that are environmental friendly and non pollutant or contaminate the environment are inevitable.

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Conflict of Interest

The authors declare that they have no competing interests.

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