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Phytochemistry of pharmacologically important medicinal plants – A Review

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Abstract

Plant derived substances have recently become of great interest owing to their versatile applications. Medicinal plants are the richest bioresource of drugs of traditional systems of medicine, modern medicines, nutraceuticals, food supplements, folk medicines, pharmaceutical intermediates and chemical entities for synthetic drugs. The beneficial medicinal effects of plant materials typically result from the combinations of secondary products present in the plant. The medicinal actions of plants are unique to particular plant species or groups are consistent with this concept as the combinations of secondary products in a particular plant are often taxonomically distinct. Ecological function of secondary products may have some bearing on potential medicinal effects for humans and the secondary products involved in plant defense through cytotoxicity toward microbial pathogens could prove useful as antimicrobial medicines in humans, if not too toxic. In contrast to synthetic pharmaceuticals based upon single chemicals, many phytomedicines exert their beneficial effects through the additive or synergistic action of several chemical compounds acting at single or multiple target sites associated with a physiological process. The present review is focused on phytochemistry and pharmacological importance of medicinal plants.

Keywords: Medicinal plants, Secondary products, Phytochemicals and Phytomedicine.

1. Introduction

Nature has been a source of medicinal agents for thousands of years and an impressive number of modern drugs have been isolated from natural sources, many based on their use in traditional medicine. Various medicinal plants have been used for years in daily life to treat disease all over the world. They have been used as a source of medicine. The widespread use of herbal remedies and healthcare preparations, such as those described in ancient texts like the Vedas and the Bible, has been traced to the occurrence of natural products with medicinal properties. In fact, plants produce a diverse range of bioactive molecules, making them a rich source of different types of medicines.

Higher plants, as sources of medicinal compounds, have continued to play a dominant role in the maintenance of human health since ancient times (Farombi, 2003; Saranraj *et al*., 2010). Over 50 % of all modern clinical drugs are of natural product origin and natural products play an important role in drug development programs in the pharmaceutical industry (Baker *et al*.,1995; Siva Sakthi *et al*., 2011).

India has a rich heritage of knowledge on plant based drugs both for use in preventive and curative medicine. A country like India is very much suited for development of drugs from medicinal plant. Because of its vase and wide variations in soil and climate, the Indian sub – continent is suitable for cultivation of large number of medicinal and aromatic plant which can be used as raw materials for pharmaceutical, perfumery, cosmetics, flavour and food and agrochemical industries. A large number of these plants grow wild and exploited especially for use in indigenous pharmaceutical houses. Some of these plants produce valuable drugs which have high export potential. (Rathish *et al*., 2005; Murugan and Saranraj, 2011).

Plant cells are highly sophisticated chemical factories where a large variety of chemical compounds are manufactured with great precision and ease from simple raw materials at normal temperature and pressure. Plants are thus a very important renewable source of raw materials for the production of a large variety of chemicals. It is estimated that there are 2,50,000 to 5,00,000 species of plants on earth. A relatively small percentage (1 – 10 %) of these is used as foods by both humans and other animal species. It is possible that even more are used for medicinal purpose (Siva Sakthi *et al*., 2011; Saranraj and Stella, 2011.

Developing a medicinal plants sector, across the various states of India has become an important issue. Different stakeholders in the medicinal plants sector have projected Tamil Nadu, one of the southern states, as an “Herbal State”. This nation has made medicinal plants as a commodity of high value across the state. At the same time, realizing the continuous depletion of this valuable resource, attempts are being made for its large-scale cultivation and multiplication in order to meet its escalating demand as well as long-term sustainability. There are many aspects of research associated with the medicinal plants sector. The significant contribution to the society, traditional medicine has experienced very little attention in modern research and development and less effort has been done to upgrade the practice (Giday *et al*., 2003; Saranraj *et al*., 2012).

The use of plants and plant products as medicines could be traced as far back as the beginning of human civilization. The earliest mention of medicinal use of plants in Hindu culture is founds in “Rig veda”, which is said to have been written between 4500 - 1600 B.C. and is supposed to be the oldest repository of human knowledge. It is Ayurveda, the foundation of medicinal science of Hindu culture, in its eight division deals with specific properties of drugs and various aspects of science of life and the art of healing (Rastogi and Mehrotra, 2002; Sekar *et al*., 2012).

Nowadays, there has been a revival of interest in herbal medicines. This is due to increased awareness of the limited ability of synthetic pharmaceutical products to control major diseases and the need to discover new molecular structures as lead compounds from the plant kingdom. Plants are the basic source of knowledge of modern medicine. The basic molecular and active structures for synthetic fields are provided by rich natural sources. This burgeoning worldwide interest in medicinal plants reflects a recognition of the validity of many traditional claims regarding the value of natural products in health care (Saranraj and Sivasakthivelan, 2012).

In the modern world multiple drug resistance has developed against many microbial infections due to the indiscriminate use of commercial antimicrobial drugs commonly used in the treatment of infectious disease. In addition to this problem, antibiotics are sometimes associated with adverse effects on the host including hypersensitivity, immune-suppression and allergic reactions. This situation forced scientists to search for new antimicrobial substances. Given the alarming incidence of antibiotic resistance in bacteria of medical importance, there is a constant need for new and effective therapeutic agents. Therefore, there is a need to develop alternative antimicrobial drugs for the treatment of infectious diseases from medicinal plants (Agarwal *et al*., 1996; Saranraj and Sivasakthi, 2014).

Plants with possible antimicrobial activity should be tested against an appropriate microbial model to confirm the activity and to ascertain the parameters associated with it. The effects of plant extracts on bacteria have been studied by a very large number of researchers in different parts of the world (Ates *et al*., 2003; Ganesh *et al*., 2014). Much work has been done on ethnomedicinal plants in India (Reddy *et al*., 2001). Interest in a large number of traditional natural products has increased (Taylor *et al*., 1996). It has been suggested that aqueous and ethanolic extracts from plants used in allopathic medicine are potential sources of antiviral, antitumoral and antimicrobial agents (Chung *et al*., 1995). The selection of crude plant extracts for screening programs has the potential of being more successful in initial steps than the screening of pure compounds isolated from natural products (Kusumoto *et al*., 1995).

Antimicrobials of plant origin have enormous therapeutic potential. They are effective in the treatment of infectious diseases while simultaneously mitigating many of the side effects that are often associated with synthetic antimicrobials. The beneficial medicinal effects of plant materials typically result from the combinations of secondary products present in the plant. In plants, these compounds are mostly secondary metabolites such as alkaloids, steroids, tannins, and phenol compounds, flavonoids, steroids, resins fatty acids gums which are capable of producing definite physiological action on body. Compounds extracted from different parts of the plants can be used to cure diarrhea, dysentery, cough, cold, cholera, fever and bronchitis (Kolanjinathan and Saranraj, 2014).

Phytochemistry is the term that deals with chemicals which was derived from plants. There are large numbers of secondary metabolic compounds found in plants. The chemical substances of the medicinal plants it has own capacity of exerting a physiological action on the human body were the primary features. The bioactive compounds of plant such as alkaloids, flavanoids, tannins and phenolic compounds were considered to be more significant. The phytochemical research usually has been done based on the ethno-pharmacological information forms the effective approach in the discovery of new anti-infective agents from higher plants (Gajalakshmi *et al*., 2012; Ramya *et al*., 2015).

Phytochemicals are a group of non-nutrient bioactive compounds naturally found in plant parts such as flowers, leaves, fruits, roots, barks, spices and medicinal plants. In humans, numerous phytochemicals have been found to be protective and preventive against many degenerative diseases such as in Ageing, Coronary heart disease, Alzheimer's disease, Neurodegenerative disorders, Atherosclerosis, Cataracts and Inflammation (Pacome *et al.,* 2014). Since ancient times, people have been exploring the nature particularly plants in search of new drugs. This has resulted in the use of large number of medicinal plants with curative properties to treat various diseases. Nearly, 80 % of the world's population relies on traditional medicines for primary health care, most of which involve the use of plant extracts. In India, almost 95 % of the prescriptions were plant based in the traditional systems of Unani, Ayurveda, Homeopathy and Siddha. The study of plants continues principally for the discovery of various novel pharmaceutically active secondary metabolites (Savithramma *et al.,* 2011; Usharani *et al*., 2015) which has pharmacologically active substances showing antifungal, antibacterial and anticancer activities. The crude extracts and active pure compounds isolated from plants species used in herbal and traditional remedies. Now, it is essential to isolate, identify and characterize the new phytochemical components of medicinal plants for the treatment of different diseases (Hossain *et al.,* 2013; Kalaiselvi *et al*., 2015).

2. Journey of medicinal plant research

An assessment of the previous trends and impact of research into the phytochemistry on medicinal plants of the world is quite desirable before considering recent trends. After centuries of empirical use of herbal preparation, the first isolation of active principles alkaloids such as morphine, strychnine, quinine etc. in the early 19th century marked a new era in the use of medicinal plants and the beginning of modern medicinal plants research. Emphasis shifted away from plant derived drugs with the tremendous development of synthetic pharmaceutical chemistry and microbial fermentation after 1945. Plant metabolites were mainly investigated from a phytochemical and chemotaxonomic viewpoint during this period. Over the last decade, however, interest in drugs of plant and probably animal origin has grown steadily (Hamburger and Hostettmann, 1991; Saranraj and Sujitha, 2015).

Utilization of medicinal plants has almost doubled in Western Europe during that period. Ecological awareness, the efficacy of a good number of phytopharmaceutical preparations, such as ginkgo, garlic or valerian and increased interest of major pharmaceutical companies in higher medicinal plants as sources for new lead structures has been the main reasons for this renewal of interest. With the development of chemical science and pharmacognosy physicians began to extract chemical products from medicinal plants. A few examples of the products extracted from medicinal plants are - in 1920, quinine was isolated from Cinchona by the French pharmacist, Peletier & Caventou. In the mid-nineteenth century, a German chemist, Hoffmann obtained Aspirin from the bark of the willow. With the active principles in medicinal plants identified and isolated, plant based prescriptions began to be substituted more and more with pure substances, which were more powerful and easier to prescribe and administer (Harvey, 2000).

Phytomedicine almost went into extinction during the first half of the 21st century due to the use of the 'more powerful and potent synthetic drug'. However, because of the numerous side effects of these drugs, the value of medicinal plants is being rediscovered as some of them have proved to be as effective as synthetic medicines with fewer or no side effects and contraindications. It has been proved that although the effects of natural remedies may seem slower, the results are sometimes better on the long run especially in chronic diseases (Akunyili, 2003; Kolanjinathan and Saranraj, 2015).

3. Pharmacology of medicinal plants

Plants have provided man with all his needs in terms of shelter, clothing, food, flavours and fragrances as not the least, medicines. Plants have formed the basis of sophisticated Traditional Medicine systems that have been in existence for thousands of years and continue to provide mankind with new remedies. Some of the oldest known medicinal systems of the world such as Ayurveda of the Indus civilization, Arabian medicine of Mesopotamia, Chinese and Tibetan medicine of the Yellow River civilization of China and Kempo of the Japanese are all based mostly on plants. The ancient cultures are known for their systematic collection of information on herbs and their rich and well-defined herbal pharmacopoeias. Although, some of the therapeutic properties attributed to plants have proven to be erroneous, medicinal plant therapy is based on the empirical findings of hundreds and thousands of years (Barathi *et al*., 2014).

Disease is as old as life itself, and man has always been in search of agents to cure diseases. Medicinal plants and herbs have been used for the eradication of disease and human suffering since antiquity. Plants that possess therapeutic properties or exert beneficial pharmacological effects on an organism are generally known as "medicinal plants". Many indigenous medicinal plants are being discovered every day. Medicinal plants used in traditional medicine should be collected at the right time, the right season, and the right stage of their growth so that the constituents can be optimally harvested (Saranraj *et al*., 2016).

Human infections constitute a serious problem especially in tropical and subtropical countries. The use of antibiotics and chemically synthesized medicines cures microbial infections very fast but they may also disturb the natural immunity of the body and cause variety of side effects. This has aroused interest in plant products which may partially support or substitute synthetic drugs. Medical communities are now trying to resolve the aforesaid problems from plant based medicines (Davvamani *et al*., 2005; Manickam *et al*., 2005; Mandal and Mondal, 2008).

Plants have a great potential for producing new drugs of large benefit to mankind (Parekh and Chandran, 2006). The World Health Organization (WHO) estimates that 80 % of the world's inhabitants rely mainly on traditional medicines for their health care. The tribal and rural people of various parts of India are highly depending on medicinal plant therapy for meeting their health care needs (Gurib Fakim, 2006; Pankajalakshmi and Taralakshmi, 2006). This attracts the attention of several botanists and plant scientists who directing vigorous researches towards the discovery or rediscovery of several medicinal plants along with their medicinal remedies for various diseases (Shanmugam *et al*., 2009; Anuraja and Shanmugam, 2010).

Many medicinal plants have proved to successfully aid in various ailments leading to mass screening for their therapeutic components. Today, the search for natural compounds rich in antimicrobial properties is escalating due to their medicinal importance in controlling many diseases (Halliwell, 1996). The rapid emergence of multiple drug resistant strains of pathogens to current antimicrobial agents has generated an urgent intensive search for new antibiotics from medicinal plants (Kaur and Arora, 2009; Mothana *et al*., 2009; Adedapo *et al*., 2009).

Plants have the major advantage of being the most effective and cheaper alternative source of drugs (Pretorius and Watt, 2001). The local use of natural plants as primary health remedies, due to their pharmacological properties is quiet common in Asia, Latin America and Africa (Bibitha *et al*., 2002). Medicinal plants contain substances that can be used for therapeutic purposes or which are used as precursors for the synthesis of useful drugs (Soforowa, 1993). Researches on use of plants as the source of drugs and dietary supplements are increasing in recent years. Plants have been found to have antimicrobial property as they are rich in a wide variety of secondary metabolites (Cowan, 1999).

Potential of higher plants as source of new drugs is still largely unexplored. Among the estimated 2,50,000 to 5,00,000 plant species, only a small percentage has been investigated phytochemically and the fraction submitted to biological and pharmacological screening was even smaller. Thus, any phytochemical investigation of a given plant will reveal only a very narrow spectrum of its constituents.

Historically, pharmacological screening of compounds of natural or synthetic origin has been the source of innumerable therapeutic agents. Random screening as tool in discovering new biologically active molecules has been most productive in the area of antibiotics (Kroschwitz, 1992). Researchers are increasingly turning their attention to natural products looking for leads to develop better drugs against many microbial infections (Hoffmann *et al*., 1993; Havery, 1999; Srinivasan *et al*., 2001). More than 80 % of the world's population relies on traditional medicine for their primary healthcare needs. Plants used in traditional medicine contain a wide range of ingredients that can be used to treat chronic as well as infectious diseases. A vast knowledge of how to use the plants accumulated in areas where the use of plants is still of great importance (Diallo *et al*., 1999). The medicinal value of plant lies in some chemical substances present in them. The most important of these bioactive compounds of plants are alkaloids, tannins and phenolic compounds (Edeoga *et al*., 2005). Consumers are increasingly interested in complementary and alternative medicines, including herbal medicine, as they perceive these forms of healing as being both safe and effective. This trend in use of alternative and complementary healthcare has prompted scientists to investigate the various biological activities of medicinal plants. A number of medicinal plants have been documented as important source of bioactive compounds (Balunas and Kinghorn, 2005).

4. Phytochemicals

Phytochemicals (from the Greek word phyto, meaning plant) are biologically active, naturally occurring chemical compounds found in plants, which provide health benefits for humans further than those attributed to macronutrients and micronutrients (Hasler and Blumberg, 1999). They protect plants from disease and damage and contribute to the plant's color, aroma and flavor. In general, the plant chemicals that protect plant cells from environmental hazards such as pollution, stress, drought, UV exposure and pathogenic attack are called as phytochemicals (Gibson *et al*., 1998; Mathai, 2000). Recently, it is clearly known that they have roles in the protection of human health, when their dietary intake is significant. More than 4,000 phytochemicals have been cataloged and are classified by protective function, physical characteristics and chemical characteristics and about 150 phytochemicals have been studied in detail (Meagher *et al*., 1999).

In wide-ranging dietary phytochemicals are found in fruits, vegetables, legumes, whole grains, nuts, seeds, fungi, herbs and spices (Mathai, 2000). Broccoli, cabbage, carrots, onions, garlic, whole wheat bread, tomatoes, grapes, cherries, strawberries, raspberries, beans, legumes, and soy foods are common sources (Moorachian, 2000). Phytochemicals accumulate in different parts of the plants, such as in the roots, stems, leaves, flowers, fruits or seeds (Costa *et al*., 1999). Many phytochemicals, particularly the pigment molecules, are often concentrated in the outer layers of the various plant tissues. Levels vary from plant to plant depending upon the variety, processing, cooking and growing conditions (King and Young, 1999). Phytochemicals are also available in supplementary forms, but evidence is lacking that they provide the same health benefits as dietary phytochemicals.

These compounds are known as secondary plant metabolites and have biological properties such as antioxidant activity, antimicrobial effect, modulation of detoxification enzymes, stimulation of the immune system, decrease of platelet aggregation and modulation of hormone metabolism and anticancer property. There are more than thousand known and many unknown phytochemicals. It is well-known that plants produce these chemicals to protect themselves, but recent researches demonstrate that many phytochemicals can also protect human against diseases (Narasinga Rao, 2003).

Phytochemicals are not essential nutrients and are not required by the human body for sustaining life, but have important properties to prevent or to fight some common diseases. Many of these benefits suggest a possible role for phytochemicals in the prevention and treatment of disease, Because of this property; many researchers have been performed to reveal the beneficial health effects of phytochemicals. The purpose of the present review is to provide an overview of the extremely diverse phytochemicals presents in medicinal plants.

5. Biological activity of phytochemicals

The phytochemicals present in plants are responsible for preventing disease and promoting health have been studied extensively to establish their efficacy and to understand the underlying mechanism of their action. Such studies have included identification and isolation of the chemical components, establishment of their biological potency both by *in vitro* and *in vivo* studies in experimental animals and through epidemiological and clinical case control studies in man. Study findings suggest that phytochemicals may reduce the risk of coronary heart disease by preventing the oxidation of low density lipoprotein (LDL) cholesterol, reducing the synthesis or absorption of cholesterol, normalizing blood pressure and clotting, and improving arterial elasticity (Walton *et al*., 2003).

Phytochemicals may detoxify substances that cause cancer. They appear to neutralize free radicals, inhibit enzymes that activate carcinogens, and activate enzymes that detoxify carcinogens. For example, according to data summarized by Meagher and Thomson, genistein prevents the formation of new capillaries that are needed for tumor growth and metastasis (Meagher *et al*., 1999). The physiologic properties of relatively few phytochemicals are well understood and more many researches has focused on their possible role in preventing or treating cancer and heart disease (Mathai, 2000). Phytochemicals have also been promoted for the prevention and treatment of diabetes, high blood pressure, and macular degeneration. While phytochemicals are classified by function, an individual compound may have more than one biological function serving as both an antioxidant and antibacterial agent (Tapas *et al*., 2008).

6. Chemical classes identified from medicinal plants

The exact classification of phytochemicals which are present in various plants could have not been performed so far, because of the wide variety of them. Phytochemicals are classified as primary or secondary constituents, depending on their role in plant metabolism and pharmacological importance. Primary constituents of plants include the common sugars, amino acids, proteins, purines and pyrimidines of nucleic acids, chlorophylls etc. Secondary constituents are the remaining plant chemicals such as alkaloids, terpenes, flavonoids, lignans, plant steroids, curcumines, saponins, phenolics, flavonoids and glucosides. Literature survey indicates that the phenolics are the most numerous and structurally diverse plant phytocontituents.

Antimicrobial activity of plant constituents such as phenolquinines, flavones, tannins, terpenoids, essential oils and alkaloids have been reported by several author (Edeoga *et al*., 2005). There is a continuous and urgent need to discover new antimicrobial with diverse chemical structures and novel mechanism of action for new and reemerging infectious disease. *Avicennia marina* is commonly known as a gray mangrove tree classified in the plant family Avicenniaceace, and is commonly used for treatment of ulcers (Subashree *et al.*, 2010), rheumatism, small pox and other ailments (Bandaranayake, 2002). Some studies were done about the antiparasitic, antifungal and antibacterial activity of *Avicennia marina* (Khatagi *et al*., 2003). *Avicennia marina* has been shown to exhibit marked inhibitory effects on mouse skin tumor promotion (Itigowa *et al*., 2001). Phenolic compounds such as phenolic acid and tannins possess diverse anticacinogenic and antialheroscteretic activities. The activities might be related to their antioxidants activity (Abeysinghe and Pathirana, 2006).

Medicinal plant extracts showed antimicrobial activity against some microorganisms, including *Shigella* sp. and *Pseudomonas* sp. (Ravikumar *et al.,* 2010). Fungal diseases are one of the major problems facing the citrus production in the entire world and resulted in enormous economic losses. *Penicillium digitatum* and *Alterneria citri* are the most devastating pathogen of citrus fruit, being responsible for about 90 % of production losses during post harvest handling (Ravikumar *et al*., 2011).
The plants and plant part extracts based biosynthesis has been found to be cost effective and environmental friendly (Casida and Quistad, 2005). But, studies related to the synthesis of nanoparticles using mangrove sand mangrove associate plants are very limited. Marine environmental conditions are extremely different from terrestrial ones. It is summarized that the mangrove plants have different characteristics from those of terrestrial plants and therefore, might produce different types of bioactive compounds (Gnanadesigan *et al*., 2011; Ravikumar *et al*., 2011). Among the different mangrove plants, *Avicennia marina* is previously proved to have antibacterial, antiplasmodial, antiviral activities (Ravikumar *et al*., 2011) and also it is proved to have high content of secondary metabolites such as polyphenols, flavonoids, alkaloids and tannins (Ravikumar *et al*., 2010).

Metabolites, some with novel chemical structures, and belonging to a diversity of 'chemical classes' have been characterized from mangroves and mangal associates. Aliphatic alcohols and acids, amino acids and alkaloids, carbohydrates, carotenoids, hydrocarbons, free fatty acids including polyunsaturated fatty acids (PUFAs), lipids, pheromones, phorbol esters, phenolics, and related compounds, steroids, triterpenes, and their glycosides, tannins, other terpenes and related compounds, are among these classes. Among the latest additions are an array of substances from gums and glues to alkaloids and saponins and other substances of interest to modern industry and medicine. Chemicals such as amino acids, carbohydrates and proteins, are products of primary metabolism and are vital for the maintenance of life processes, while others like alkaloids, phenolics, steroids, terpenoids, are products of secondary metabolism and have toxicological, pharmacological and ecological importance.

6.1. Heterocyclic compounds

Heterocycles are those molecules having rings composed of both carbon and one or more heteroatoms, chiefly, nitrogen, oxygen and sulfur. They can be unsaturated or 'aromatic' heterocycles or saturated heterocycles, and are usually be five or six member. They exist either as 'independent' rings or fused normally to benzene rings. Alkaloids, chromenes, coumarins, flavonoids, xanthones etc. belong to this general class.

6.2. Alkaloids

Alkaloids are nitrogenous bases (usually heterocyclic), and are structurally the most diverse class of secondary metabolites (Geissman and Crout, 1969). They range from simple structures to complex ones such as those of many neurotoxins. In very rare instances they contain sulfur, as encountered in the diothiolanes isolated from species of *Brugeira.* Their manifold pharmacological activities have always excited man's interest, and selected plant products containing alkaloids have been used as poison for hunting, murder and euthanasia, as euphoriants, psychedelics, stimulants and medicine. Basic nitrogen compounds from higher plants include many representatives that are potent inhibitors of various oxidative processes both *in vivo* and *in vitro*.

6.3. Carbohydrates, Lignins and Polysaccharides

The carbohydrates or saccharides ('hydrate of carbon') of general formula $C_n(H_2O)n$ are mostly sweet compounds (hence the term sugar) are found abundantly in higher terrestrial plants, fungi, and seaweed and consist of compounds such as sugars, starch, and cellulose (Geissman and Crout, 1969.). The simple sugars or monosaccharides of known molecular weight are either polyhydroxy aldehydes or ketones. Glucose is by far the most common carbohydrate, and although it occurs free in a variety fruit juices, honey etc., it is more commonly encountered in polymers such as cellulose and starch which are termed polysaccharides. Lignins are non-carbohydrate polymers present in wood. The insoluble polysaccharide in plant is cellulose, while soluble polysaccharides serve as carbohydrate food storage: Starch in plants and glycogen in animals. Polysaccharides of plant origin have emerged as important class of bioactive natural products. Those isolated from fungi usually show anti-tumor activity, while polysaccharides of higher plants possess immunostimulatory, anti-complementary, anti-inflammatory, hypoglycemic, and anti-viral activities and algal polysaccharides, which often contain sulfate anions, are good anti-coagulants. Carbohydrates in general, are essential constituents of all living organisms and are associated with a variety of vital functions, which sustain life.

6.4. Fatty acids and lipids

Fatty acids are long chain alkanoic acids and refer principally to straight chain, saturated or unsaturated monocarboxylic acids with an even number of carbon atoms, usually 12 to 28 in number. The term also includes Polyunsaturated Fatty Acids (PUFA's) and such derived structures as unsaturated, hydroxylated, branched acids. These fatty acids are ubiquitous in nature. They are found only in trace amounts in living cells in their free, unesterified form, and are of greatest importance as components of lipids which, upon alkaline hydrolysis, afford the alkali metal salts of the fatty acids other components. These include the acylglycerols, the waxes and other species.

6.5. Anthocyanins, Flavonoids, Phenolics and Quinones

The expression 'phenolic compounds' embraces a vast range of organic substances, which are aromatic compounds with hydroxyl substituents and some possessing antibiotic properties. Most are polyphenolic and flavonoids form the largest group, which occur widely in the plant kingdom (Geissman and Crout. 1969.) However, phenolic quinones, lignans, xanthones, coumarins and other classes exist in considerable numbers. In addition to monomeric and dimeric structures, there are three important groups of phenolic polymers- lignins, black melanin pigments of plants, and the tannins of woody plants.

Plant polyphenols are economically important because they make major contributions to the taste and flavor (tea, and beer), and color (red wine) of our food and drink. In nature, phenolics protect plants from herbivores, and act as chemical signals in the flowering and pollination and in the process of plant symbiosis and parasitism. It has been recognized for some time that several classes of flavonoids play a significant role in many physiological processes and show antioxidant and fungicidal activity (Larson, 1988.) and are natural antihistamines.

Flavonoid, and flavonol-lignan derivatives inhibit lipid peroxidation and are potent quenchers of triplet oxygen. A variety of modifications of the flavonoid skeleton lead to a large class of compounds that includes isoflavones, isoflavonones and chalcones, Some isoflavones are now been marketed as therapeutic agents for menstrual disorders. Polyhydroxylated chalcones, such as those found in *Pongamia pinnata*, which are biosynthetic intermediates between cinnamic acids and flavonoids also show considerable antioxidant activity. Anthocyanins, are pigments, which occur as glycosides (often glucosides), hydrolysis of, which provides colored aglycones, known as anthocyanidins. The isoflavone, rotenone is a natural insecticide. The term 'proanthocyanidin' is not structurally explicit, but is based solely upon the experimental observation that these colorless compounds yield anthocyanidins upon treatment with strong acids (Scalbert, 1991: Stafford, 1988). They are astringent to the taste and have the ability to tan leather. Indeed, the so called 'condensed tannins' belong to this class of substances. 'Oxidized' phenolic compounds are commonly referred to as quinones.

6.6. Phytoalexins

A wide range of organic compounds, collectively called phytoalexins, many of them fungitoxic or fungistatic, appear in the sapwood of trees after wounding, injury or fungal attack. A diverse range of chemical classes including alcohols, alkaloids, flavonoids, lignans, polyketides, polyacetylenes, quinones, stilbene-derived compounds and terpenes have been identified as phytoalexins.

6.7. Tannins

Tannins are polyphenolic substances widely distributed among higher plants. They differ from most other natural phenolic compounds in their ability to precipitate proteins such as gelatin from solution. This property, sometimes called astringency, is the reason for their past and present use in the tanning of animal skin. Tannins are distributed in two groups according to their structures: Proanthocyanidins (condensed tannins) and hydrolysable or water-soluble tannins (Scalbert, 1991; Stafford, 1988). The class of natural polymers variously referred to as condensed tannins, flavotannins, proanthocyanidins or flavolans have the general formula, with 'n' varying from 2 to 20. Upon heating with alcoholic hydrochloric acid, they yield anthocyanidin pigments.

Proanthocyanidins are found in many food products such as tea, cocoa, sorghum or carob pods. Hydrolysable tannins are esters of phenolic acids (e.g. gallic acid and gallotannins) and a polyol, which is usually glucose. The leather tanning industry requires water-soluble tannins. Although tannins probably evolved in plants as a defense against microbial attack, they are also instrumental in regulating terrestrial herbivory from predation, either by increasing resistance against pathogens or by protecting essential tissues such as wood against decay. Increasing attention is also being paid to the use of tannins as antimicrobial agents (e.g. wood preservation) or prevention of dental caries. They impart flavor to wines. Recently, evidence has been obtained in support of their potential value as cytotoxic or antineoplastic agents. In addition, tannins are now being used in the manufacture of plastics, paints, ceramics and water softening agents. Members of the families Avicenniaceae, Rhizophoraceae, and Sonneratiaceae are rich source of tannins (Bandaranayake, 1995).

6.8. Limonoids, Terpenes, Steroids and Saponins

The diverse, widespread, and exceedingly numerous family of natural products constructed from five carbon building-units (isoprenyl carbon skeleton) and so comprising compounds with C5, C10, C15, C20, C40 skeletons, are synonymously termed terpenoids, terpenes, or isoprenoids, with the important subgroup of steroids sometimes singled out as a class in its own right. However, as more and more terpenoid compounds were discovered, their structures departed from, or 'violated' this 'isoprene' rule. These compounds are typically found in all parts of higher plants and also occur in mosses, liverworts, algae etc. Members of the class, as components of oil or in extracts, have been used since antiquity as ingredients of flavors, preservatives, perfumes, medicines, narcotics, soaps and pigments. The number of isoprene units they contain in their structures subdivides terpenes into monoterpenes (C10 compounds), sesquiterpenes (C15) diterpenes (C20) and triterpenes (C30). Triterpenes are the most common terpenes in plants, usually with pentacyclic structures like those of amyrin. The most common example of tetraterpenes (C40) are the carotenoids, which are pigments whose principal recognized role is to act as photoreceptive 'antenna pigments' for photosynthesis. Some of them also have a protective function against oxidative damage. Some of the terpenes were known from antiquity and were employed as medicines.

Steroids are merely modified triterpenes and are widespread in both animal and plant kingdoms and many microorganisms. The saponins have attracted much attention in recent years because of their varied biological properties, some of which are deleterious, but many of which are beneficial to human health (Mahato., 1988). They are plant glycosides, which have the property of forming a soapy lather when shaken with water. They are used in traditional and modern medicine and in food and agriculture and are classified as steroidal or triterpenoidal saponins depending upon the nature of the aglycone: The sapogenin. A third groups of saponins, which are called basic steroid saponins, contain nitrogen analogues of steroid sapogenins as aglycones. The primitive people knew the use of saponins as natural detergents and the leaves containing them are used as natural soaps. Most molluscicides of plant origin are saponins and these compounds are toxic to fish. Triterpenoidal saponins exhibit divergent antimicrobial, anti-inflammatory, antibiotic, hemolytic analgesic, hypoglycemic, anthelmintic and cytotoxic activities.

The use of plant saponins in a liposomal drug delivery system has been demonstrated. The interesting pharmacological properties associated with the Chinese drug 'ginseng', which is considered a panacea and a drug for longevity, is attributed to the various saponins present in it. Steroidal saponins are commercially sought after as starting materials for the synthesis of steroidal hormones. Limonoids are modified triterpenes. They are the most distinctive secondary metabolites of the plant order Rutales. In particular, they characterize members of the family Meliaceae, where they are diverse and abundant and to a limited extent, in the family Rutaceae. Recently, limonoids have attracted much attention because of the marked insect antifeedant, insecticidal, antifungal, bactericidal, and antiviral activity, growth regulating properties, and a variety of medicinal effects in animals and humans (Champagne *et al.,* 1992). The bitterness of fresh citrus juice is due to flavonones. The bitter taste gradually increases after expression and the causative factor was found to be due to limonoids.

7. Conclusion

The phytochemical analysis of the medicinal plants are also important and have commercial interest in both research institutes and pharmaceuticals companies for the manufacturing of the new drugs for treatment of various diseases. With the present information are reported in this review, it is difficult to establish clear functionality and structure activity relationships regarding the effects of phytochemicals in biological systems activity. This is largely due to the occurrence of a vast number of phytochemicals with similar chemical structures, and to the complexity of physiological reactions. Moreover, given the number of phytochemicals isolated so far, nature must still have many more in store. With the advances in synthetic methodology and the development of more sophisticated isolation and analytical techniques, many more of these phytochemicals should be identified.

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