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Phytochemical Screening of Indian Plants Used As Medicine

Bholenath Birla
Head of Department of Pharmacognosy, Charak Institute of Pharmacy, Mandleshwar, Khargone-451221

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ABSTRACT
Medicinal plants are a rich source of bioactive phytochemicals or bionutrients. Studies carried out during the past 2– 3 decades have shown that these phytochemicals have an important role in preventing chronic diseases like cancer, diabetes and coronary heart disease. The major classes of phytochemicals with disease-preventing functions are dietary fibre, antioxidants, anticancer, detoxifying agents, immunity-potentiating agents and neuropharmacological agents. Each class of these functional agents consists of a wide range of chemicals with differing potency. Some of these phytochemicals have more than one function. There is, however, much scope for further systematic research in screening Indian medicinal plants for these phytochemicals and assessing their potential in protecting against different types of diseases.

Keyword: Phytochemical, Alkaloids, Terpenoids, Flavonoids, Saponins, Tannins and Phenolics.

I. INTRODUCTION

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[1]. 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[2,3] . 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[4] and are classified by protective function, physical characteristics and chemical characteristics[5] and About 150 phytochemicals have been studied in detail[4] . In wide-ranging dietary phytochemicals are found in fruits, vegetables, legumes, whole grains, nuts, seeds, fungi, herbs and spices[3]. Broccoli, cabbage, carrots, onions, garlic, whole wheat bread, tomatoes, grapes, cherries, strawberries, raspberries, beans, legumes, and soy foods are common sources[6] . Phytochemicals accumulate in different parts of the plants, such as in the roots, stems, leaves, flowers, fruits or seeds [7] . 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[8] . Phytochemicals are also available in supplementary forms, but evidence is lacking that they provide the same health benefits as dietary phytochemicals[4] . 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[9] .

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.

II. THE 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[10] . 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 [11] . 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 beas 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[12] .

III. BIOLOGICAL ACTIVITIES 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 lowdensity lipoprotein (LDL) cholesterol, reducing the synthesis or absorption of cholesterol, normalizing blood pressure and clotting, and improving arterial elasticity[3,13] . 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[5] . The physiologic properties of relatively few phytochemicals are well understood and more many research has focused on their possible role in preventing or treating cancer and heart disease[3] . Phytochemicals have also been promoted for the prevention and treatment of diabetes, high blood pressure, and macular degeneration[4] . While phytochemicals are classified by function, an individual compound may have more than one biological function serving as both an antioxidant and antibacterial agent [13]. Bioactive and Diseasepreventing phytochemicals present in plant are shown in Table 1.

Table 1. Bioactive Phytochemicals In Medicinal Plants.

Classification	Main groups of compounds	Biological function
NSA(Non-starch polysaccharides.)	Cellulose, hemicellulose, gums, mucilages, pectins, lignins	Water holding capacity, delay in nutrient absorption, binding toxins and bile acids
Antibacterial & Antifungal	Terpenoids, alkaloids, phenolics	Inhibitors of micro-organisms, reduce the risk of fungal infection
Antioxidants	Polyphenolic compounds, flavonoids, carotenoids,	Oxygen free radical quenching, inhibition of lipid peroxidation

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	tocopherols, ascorbic acid	
Anticancer	Carotenoids, polyphenols, curcumine, Flavonoids	Inhibitors of tumor, inhibited development of lung cancer, anti-metastatic activity
Detoxifying Agents	Reductive acids, tocopherols, phenols, indoles, aromatic isothiocyanates, coumarins, flavones, carotenoids, retinoids, cyanates, phytosterols	Inhibitors of procarcinogen activation, inducers of drug binding of carcinogens, inhibitors of tumourogenesis
Other	Alkaloids, terpenoids, volatile flavor compounds, biogenic amines	Neuropharmacological agents, anti-oxidants, cancer chemoprevention

IV. CLASSIFICATION OF PHYTOCHEMICALS

The exact classification of phytochemicals could have not been performed so far, because of the wide variety of them. In resent year Phytochemicals are classified as primary or secondary constituents, depending on their role in plant metabolism. Primary constituents include the common sugars, amino acids, proteins, purines and pyrimidines of nucleic acids, chlorophyll's etc. Secondary constituents are the remaining plant chemicals such as alkaloids, terpenes, flavonoids, lignans, plant steroids, curcumines, saponins, phenolics, flavonoids and glucosides[14] . Literature survey indicate that phenolics are the most numerous and structurally diverse plant phytocontituents. (Figure 2).

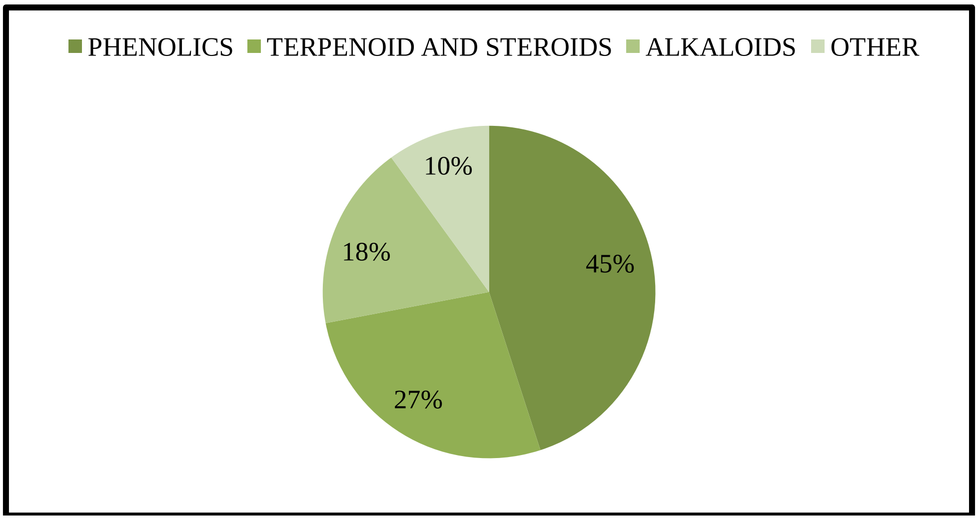

Fig.2: Pie chart representing the major groups of plant Phytochemicals.

V. PHENOLICS

Phenolic phytochemicals are the largest category of phytochemicals and the most widely distributed in the plant kingdom. The three most important groups of dietary phenolics are flavonoids, phenolic acids, and polyphenols. Phenolic are hydroxyl group (-OH) containing class of chemical compounds where the (-OH) bonded directly to an aromatic hydrocarbon group. Phenol ($C6H5OH$) is considered the simplest class of this group of natural compounds. Phenolic compounds are a large and complex group of chemical constituents found in plants[15] . They are plant secondary metabolites, and they have an important role as defence compounds. phenolics exhibit several properties beneficial to humans and its antioxidant properties are important in determining their role as protecting agents against free radical-mediated disease processes. Flavonoids are the largest group of plant phenols and the most studied[16] . Phenolic acids form a diverse group that includes the widely distributed hydroxybenzoic and hydroxycinnamic acids. Phenolic polymers, commonly known as tannins, are compounds of high molecular weight that are divided into two classes: hydrolyzable and condensed tannins.[6]. Phenolic acids The term "phenolic acids", in general, designates phenols that possess one carboxylic acid functional group. Naturally occurring phenolic acids contain two distinctive carbon frameworks: the hydroxycinnamic and hydroxybenzoic structures (Figure3). Hydroxycinnamic acid compounds are produced as simple esters with glucose or hydroxy carboxylic acids. Plant phenolic compounds are different in molecular structure, and are characterized by hydroxylated aromatic rings[17] . These compounds have been studied mainly for their properties against oxidative damage leading to various degenerative diseases, such as cardiovascular diseases, inflammation and cancer. Indeed, tumour cells, including leukaemia cells, typically have higher levels of reactive oxygen species (ROS) than normal cells so that they are particularly sensitive to oxidative stress[18] . Many papers and reviews describe studies on bioavailability of phenolic acids, emphasizing both the direct intake through food consumption and the indirect bioavailability deriving by gastric, intestinal and hepatic metabolism[19] .

Table 2: The Major Classes of Phenolic Compounds in Plants

S.no.	Number of carbon atom	Basic skeletal	Class
1	6	C_6	Simple phenols Benzoquinones
2	7	C_6-C_1	Phenolic acids
3	8	C_6-C_2	Acetophenones Tyrosine derivatives
4	9	C_6-C_3	Hydroxycinnamic acid, Coumarins
5	10	C_6-C_4	Naphthoquinones
6	13	C_6-C_1-C_6	Xanthones
7	14	C_6-C_2-C_6	Stilbenes
8	15	C_6-C_3-C_6	Flavonoids
9	18	$(C_6\text{-}C_3)_2$	Lignans
10	30	$(C_3\ C_6\text{-}\ C_6)_2$	Bioflavonoids
11	N	$(C_3\ C_6\text{-}\ C_6)_n$	C6)n Condensed tannins

In addition Phenolic acid compounds and functions have been the subject of a great number of agricultural, biological, chemical and medical studies. In recent years, the importance of antioxidant activities of phenolic compounds and their potential usage in processed foods as a natural antioxidant compounds has reached a new level and some evidence suggests that the biological actions of these compounds are related to their antioxidant activity[20] .

5.1 Activity of Phenolic Acids

Phenolic compounds are famous group of secondary metabolites with wide pharmacological activities. Phenolic acid compounds and functions have been the subject of a great number of agricultural, biological, chemical and medical studies. Phenolic compounds in many plants are polymerized into larger molecules such as the proanthocyanidins (PA; condensed tannins) and lignins. Moreover, phenolic acids may arise in food plants as glycosides or esters with other natural compounds such as sterols, alcohols, glucosides and hydroxyfatty acids. Varied biological activities of phenolic acids were reported. Increases bile secretion, reduces blood cholesterol and lipid levels and antimicrobial activity against some strains of bacteria such as staphylococcus aureus are some of biological activities of phenolic acids[21] . Phenolics acid possesses diverse biological activities, for instance, antiulcer, anti- inflammatory, antioxidant[22], cytotoxic and antitumor, antispasmodic, and antidepressant activities[23] .

VI. FLAVONOIDS

Flavonoids are polyphenolic compounds that are ubiquitous in nature. More than 4,000 flavonoids have been recognised, many of which occur in vegetables, fruits and beverages like tea, coffee and fruit drinks[24] . The flavonoids appear to have played a major role in successful medical treatments of ancient times, and their use has persisted up to now. Flavonoids are ubiquitous among vascular plants and occur as aglycones, glucosides and methylated derivatives. More than 4000 flavonoids have been described so far within the parts of plants normally consumed by humans and approximately 650 flavones and 1030 flavanols

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are known[25] . Small amount of aglycones (i.e., flavonoids without attached sugar) are frequently present and occasionally represent a considerably important proportion of the total flavonoid compounds in the plant. Figure 4, represents major flavonoids' structures. The six-membered ring condensed with the benzene ring is either -pyrone (flavones and flavonols) or its dihydroderivative (flavanones and flavan-3-ols). The position of the benzenoid substituent divides the flavonoids into two classes: flavone (2-position) and isoflavone (3-position). Most flavonoids occur naturally associated with sugar in conjugated form and, within any one class, may be characterized as monoglycosidic, diglycosidic, etc. The glycosidic linkage is normally located at position 3 or 7 and the carbohydrate unit can be L-rhamnose, Dglucose, glucorhamnose, galactose or arabinose[26] .

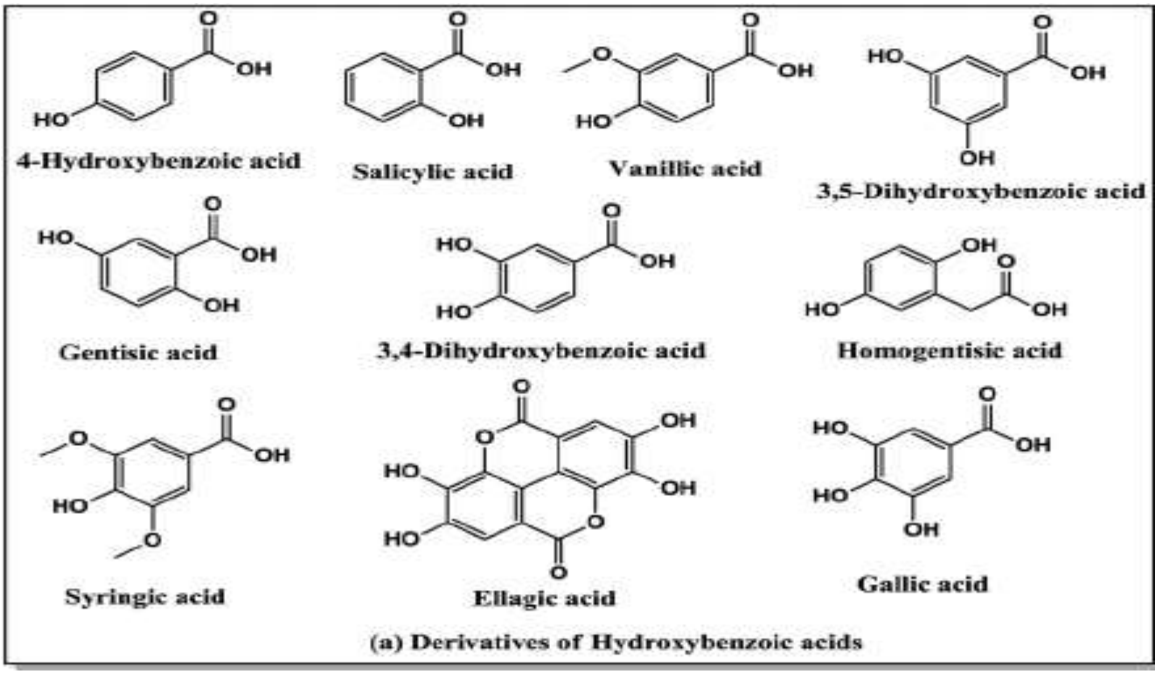

Fig. 3. Structures of the important naturally occurring phenolic acids.

6.1 Activity of Flavonoids

Flavonoids have gained recent attention because of their broad biological and pharmacological activities in these order Flavonoids have been reported to exert multiple biological property including antimicrobial, cytotoxicity, antiinflammatory as well as antitumor activities but the best-described property of almost every group of flavonoids is their capacity to act as powerful antioxidants which can protect the human body from free radicals and reactive oxygen species. The capacity of flavonoids to act as antioxidants depends upon their molecular structure. The position of hydroxyl groups and other features in the chemical structure of flavonoids are important for their antioxidant and free radical scavenging activities. On the other hand flavonoids such as luteolin and cathechins, are better antioxidants than the nutrients antioxidants such as vitamin C, vitamin E and β-carotene. Flavonoids have been stated to possess many useful properties, containing anti-inflammatory activity, enzyme inhibition, antimicrobial activity, oestrogenic activity, anti-allergic activity, antioxidant activity, vascular activity and cytotoxic antitumor activity[27] . Flavonoids constitute a wide range of substances that play important role in protecting biological systems against the harmful effects of oxidative processes on macromolecules, such as carbohydrates, proteins, lipids and DNA[28] .

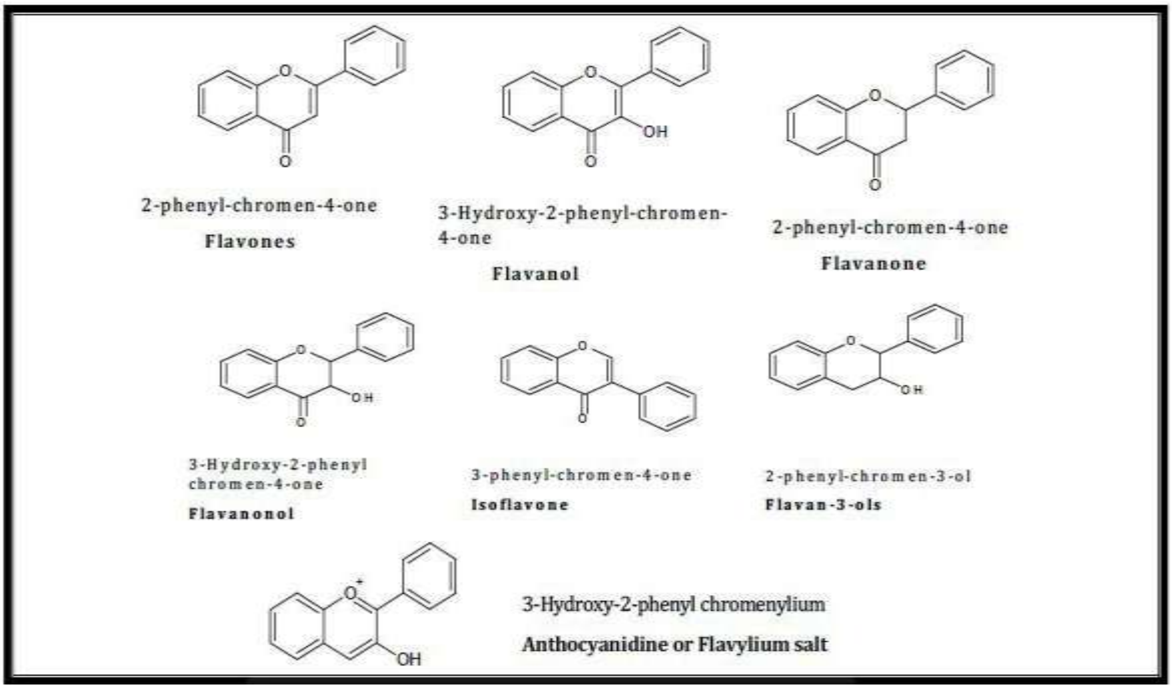

Fig.4. Chemical structures of some representative flavonoids.

VII. TANNIN

From a chemical point of view it is difficult to define tannins since the term encompasses some very diverse oligomers and polymers[29,30] . It might be said that the tannins are a heterogeneous group of high molecular weight polyphenolic compounds with the capacity to form reversible and irreversible complexes with proteins (mainly), polysaccharides (cellulose, hemicellulose, pectin, etc.), alkaloids, nucleic acids and minerals, etc[31,32,33] . On the basis of their structural characteristics it is therefore possible to divide the tannins into four major groups: Gallotannins, ellagitannins, complex tannins, and condensed tannins[34,35,36] (Figure 5). (1) Gallotannins are all those tannins in which galloyl units or their meta-depsidic derivatives are bound to diverse polyol-, catechin-, or triterpenoid units. (2) Ellagitannins are those tannins in which at least two galloyl units are C–C coupled to each other, and do not contain a glycosidically linked catechin unit. (3) Complex tannins are tannins in which a catechin unit is bound glycosidically to a gallotannin or an ellagitannin unit. (4) Condensed tannins are all oligomeric and polymeric proanthocyanidins formed by linkage of C-4 of one catechin with C-8 or C-6 of the next monomeric catechin. Tannins are found commonly in fruits such as grapes, persimmon, blueberry, tea, chocolate, legume forages, legume trees like Acacia spp., Sesbania spp., in grasses i.e; sorghum, corn, etc[37] . Several health benefits have been recognized for the intake of tannins and some epidemiological associations with the decreased frequency of chronic diseases have been established [38]

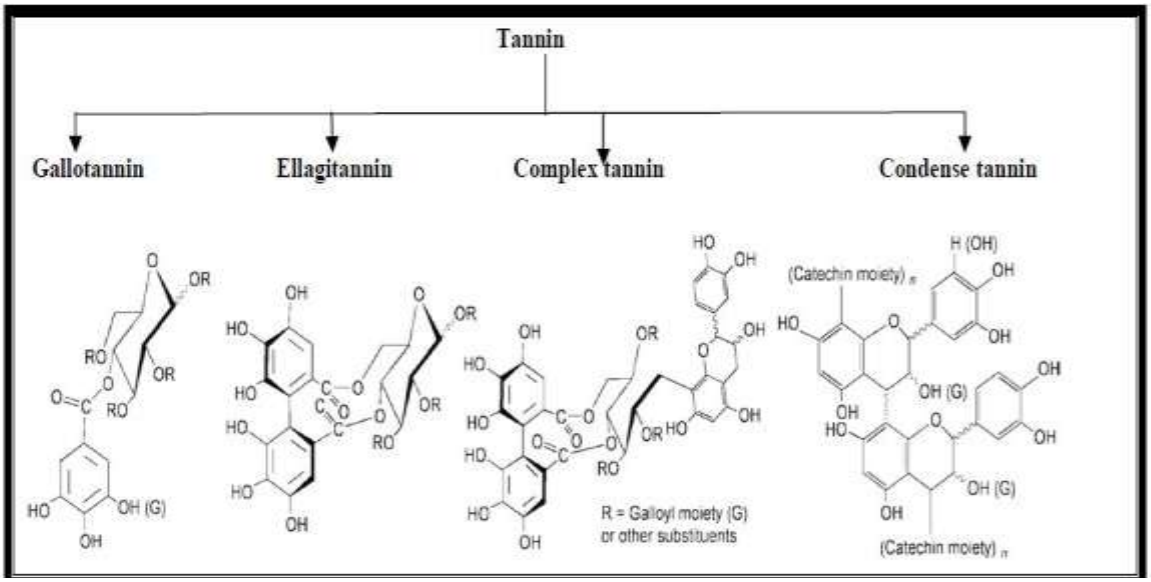

Fig.5. Classification of tannins.

7.1 Activity of Tannins

In medicine, especially in Asian (Japanese and Chinese) natural healing, the tannin-containing plant extracts are used as astringents, against diarrhoea, as diuretics, against stomach and duodenal tumours[39] , and as antiinflammatory, antiseptic, antioxidant and haemostatic pharmaceuticals[40] . Tannins are used in the dyestuff industry as caustics for cationic dyes (tannin dyes), and also in the production of inks (iron gallate ink). In the food industry tannins are used to clarify wine, beer, and fruit juices. Other industrial uses of tannins include textile dyes, as antioxidants in the fruit juice, beer, and wine industries, and as coagulants in rubber Production41 . Recently the tannins have attracted scientific interest, especially due to the increased incidence of deadly illnesses such as AIDS and various cancers[42] . The search for new lead compounds for the development of novel pharmaceuticals has become increasingly important, especially as the biological action of tannin-containing plant extracts has been well documented[43,44] .

VIII. ALKALOIDS

Alkaloids are natural product that contains heterocyclic nitrogen atoms, are basic in character. The name of alkaloids derives from the “alkaline” and it was used to describe any nitrogen-containing base[45] . Alkaloids are naturally synthesis by a large numbers of organisms, including animals, plants, bacteria and fungi. Some of the fires natural products to beisolated from medicinal plants were alkaloids when they first obtained from the plants materials in the early years of 19th century, it was found that they were nitrogen containing bases which formed salts with acid. Hence they were known as the vegetable alkalis or alkaloids and these alkaloids are used as the local anesthetic and stimulant as cocaine[46] . Almost all the alkaloids have a bitter taste. The alkaloid quinine for example is one of the bitterest tasting substances known and is significantly bitter (1x10-5) at a molar concentration[47] . Alkaloids are so numerous and involve such a variety of molecular structure that their rational classification is difficult. However, the best approach to the problem is to group them into families, depending on the type of heterocyclic ring system present in the molecule[48] . For historicxal reasons as also because of their structural complexities, the nomenclature of alkaloids has not been systematized. The names of individual members are, therfour, generally derived from the name of the plant in which they occur, or from their characteristic physiological activity.the various classes of alkaloids according to the heterocyclic ring system they contain are listed below. Pyrrolidine alkaloids: they contain pyrrolidine (tetrahydropyrrole) ring system. E.g Hygrine found in Erythroxylum coca leaves. Pyridine alkaloids: they have piperidine (hexahydropyridine) ring system. E.g Coniine, piperine and isopelletierine. Pyrrolidine-pyridine alkaloids: the heterocyclic ring system present in there alkaloids is Pyrrolidinepyridine.E.g Myosmine, Nicotine alkaloid found in tobacco (Nicotiana tabacum) plant. Pyridine-piperidine

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alkaloids:This family of alkaloids contains a pyridine ring system join to a piperidine ring system the simplest member is Anabasine alkaloid isolated from poisonous Asiatic plant anabasis aphyllan. Quinoline Alkaloids: These have the basic heterocyclic ring system quinoline .E.g Quinine occurs in the bark of cinchona tree.It has been used for centuries for treatment of malaria.Synthetic drugs such as primaquinine have largely replace quinine as an anti-malarial. Isoquinoline alkaloids: They contain heterocyclic rig system isoquinoline. E.g Opium alkaloids like narcotine, papaverine, morphine, codeine, and heroine.

8.1. Activity of Alkaloids

Alkaloids are significant for the protecting and survival of plant because they ensure their survival against micro-organisms (antibacterial and antifungal activities), insects and herbivores (feeding deterrens) and also against other plants by means of allelopathically active chemicals[49] . The useof alkaloids containing plants as dyes, spices, drugs or poisons can be traced back almost to the beginning of civilization. Alkaloids have many pharmacological activities including antihypertensive effects (many indole alkaloids), antiarrhythmic effect (quinidine, spareien), antimalarial activity (quinine), andanticancer actions (dimeric indoles, vincristine, vinblastine). These are just a few example illustrating the great economic importanceof this group of plant constituents[50] . Some alkaloids have stimulant property as caffeine and nicotine, morphine are used as the analgesic and quinine as the antimalarial drug[46] .

IX. TERPENOIDS

The terpenoids are a class of natural products which have been derived from five-carbon isoprene units. Most of the terpenoids have multi cyclic structures that differ from one another by their functional groups and basic carbon skeletons. These types of natural lipids can be found in every class of living things, and therefore considered as the largest group of natural products[51] . Many of the terpenoids are commercially interesting because of their use as flavours and fragrances in foods and cosmetics examples menthol and sclareol or because they are important for the quality of agricultural products, such as the flavour of fruits and the fragrance of flowers like linalool[52] . Terpenes are widespread in nature, mainly in plants as constituents of essential oils. Their building block is the hydrocarbon isoprene, CH2=C(CH3)-CH=CH2. Terpene hydrocarbons therefore have molecular formula (C5H8) n and they are classified according to the number of isoprene units[53] .

9.1 Hemiterpenoids:

Consist of a single isoprene unit. The only hemiterpene is the Isoprene itself, but oxygen-containing derivatives of isoprene such as isovaleric acid and prenol is classify as hemiterpenoids.

9.2 Monoterpenoids:

Biochemical modifications of monoterpenes such as oxidation or rearrangement produce the related monoterpenoids. Monoterpenoids have two isoprene units. Monoterpenes may be of two types i.e linear (acyclic) or contain rings e.g. Geranyl pyrophosphate, Eucalyptol, Limonene, Citral, Camphor and Pinene.

9.3 Sesquiterpenes:

Sesquiterpenes have three isoprene units e.g. Artemisinin, Bisabolol and Fernesol, oil of flowers, or as cyclic compounds, such as Eudesmol, found in Eucalyptus oil.

9.4 Diterpenes:

It composed for four isoprene units. They derive from geranylgeranyl pyrophosphate. There are some examples of diterpenes such as cembrene, kahweol, taxadiene and cafestol. Retinol, retinal, and phytol are the biologically important compounds while using diterpenes as the base.

9.5 Triterpenes:

It consists of six isoprene units e.g. Lanosterol and squalene found in wheat germ, and olives.

9.6 Tetraterpenoids:

It contains eight isoprene units which may be acyclic like lycopene, monocyclic like gamma-carotene, and bicyclic like alpha- and betacarotenes.

9.7 Activity of Terpenes

Among plant secondary metabolites terpenoids are a structurally most diverse group; they function as phytoalexins in plant direct defense, or as signals in indirect defense responses which involves herbivores and their natural enemies[54] . Many plants produce volatile terpenes in order to attract specific insects for pollination or otherwise to expel certain animals using these plants as food. Less volatile but strongly bitter-tasting or toxic terpenes also protect some plants from being eaten by animals (antifeedants)[55]. Last, but not least, terpenes play an important role as signal compounds and growth regulators (phytohormones) of plants, as shown by preliminary investigations. In addition, terpenoids can have medicinal properties such as anticarcinogenic (e.g. perilla alcohol), antimalarial (e.g. artemisinin), anti-ulcer, hepaticidal, antimicrobial or diuretic (e.g. glycyrrhizin) activity and the sesquiterpenoid antimalarial drug artimisinin and the diterpenoid anticancer drug taxol.[53,56] .

X. SAPONIN

Saponins are a group of secondary metabolites found widely distributed in the plant kingdom They form a stable foam in aqueous solutions such as soap, hence the name "saponin". Chemically, saponins asa group include compounds that are glycosylated steroids, triterpenoids, and steroid alkaloids. Two main types of steroid aglycones are known, spirostan and furostan derivatives (Figure 8A,B, respectively). The main triterpene aglycone is a derivative of oleanane (Figure 8C) [57] . The carbohydrate part consists of one or more sugar moieties containing glucose, galactose, xylose, arabinose, rhamnose, or glucuronic acid glycosidically linked to a sapogenin (aglycone). Saponins that have one sugar molecule attached at the C-3 position are called monodesmoside saponins, and those that have a minimum of two sugars, one attached to the C-3 and one at C-22, are called bidesmoside saponins[58]

10.1 Activity of Saponins

The physiological role of saponins in plants is not yet fully understood. While there is a number of a publication describing their identification in plants, and their multiple effects in animal cells and on fungi and bacteria, only a few have addressed their function in plant cells. Many saponins are known to be antimicrobial, to inhibit mould, and to protect plants from insect attack. Saponins may be considered a part of plants' defence systems, and as such have been included in a large group of protective molecules found in plants named phytoanticipins or phytoprotectants[59] . Saponin mixtures present in plants and plant products possess diverse biological effects when present in the animal body. Extensive research has been carried out into the membrane-permeabilising, immunostimulant, hypocholesterolaemic and anticarcinogenic properties of saponins and they have also been found to significantly affect growth, feed intake and reproduction in animals. These structurally diverse compounds have also been observed to kill protozoans and molluscs, to be antioxidants, to impair the digestion of protein and the uptake of vitamins and minerals in the gut, to cause hypoglycaemia, and to act as antifungal and antiviral[60,61,62] .

XI. CONCLUSION

Nature is a unique source of structures of high phytochemical diversity, many of them possessing interesting biological activities and medicinal properties. In the context of the worldwide spread different diseases such as AIDS, chronic diseases and a variety of cancers, an intensive search for new lead compounds for the development of novel pharmacological therapeutics is extremely important. 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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