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PLANT SECONDARY METABOLITES AND THEIR USES

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Abstract

Plant extracts and their use in daily life as a medication, flavoring agent, preservative and even as a poison was known since ages. Recently with the advancement in the extraction and characterization techniques, it becomes possible to separate and characterize several bioactive compounds from the crude plant extract. Various studies have shown promising result results regarding the pharmacological importance of the plant secondary metabolites. Furthermore, nowadays genes of these secondary metabolites are genetically engineered and were even made to express in other organisms that too in high concentrations. More studies are needed to be done to explore and validate the pharmacological potential of such bioactive compounds, since these compounds are the important source of drug candidates for the pharmaceutical industries.

Keywords: Plant secondary metabolites, pharmaceutical, anti-microbial, alkaloids, polyphenols, terpenes, terpenoids, saponins, steroids.

Introduction

Plant secretes many organic compound that don't have direct role to play in the photosynthesis, growth and development but indirectly plays a role in the plant survival by performing many important functions like, such compounds may be secreted by plants as a signaling molecules, may have role in preventing herbivores, may act as an anti-microbial, etc. Ancient texts from India also showed the use of plants and their extracts as a medicine for the treatment of various human ailments. With the advent in the technology nowadays it becomes easier to isolate and characterize secondary metabolites from the crude plant extracts (Crozier, Clifford, & Ashihara, 2008). The secondary plant metabolites are produced by plants via different primary metabolic pathways. These are those organic compounds, absence of which does not lead to the instant death of the plant but rather, lead to the long term which, unlike primary metabolites, but rather in long-term deterioration of the respective plant's aesthetics, productivity as well as its endurance. The secondary metabolites were also known to have antifungal, antibiotic and antiviral ability, thus holding a significant position in maintaining the plant's defense system due to their toxicity, hence they repel other microbes and herbivores, thereby protecting them from any kind of pathogens. This concept of secondary metabolites was firstly mentioned by Albrecht Kossel, who won the Noble Prize in the year 1910 for Medicine (Jones, 1953). Post thirty years, the secondary metabolites were explained to be the end products by Czapek, who believed them that they were to be obtained from the metabolism of nitrogen (Bourgaud *et al*., 2001). Also, these secondary metabolites comprise of various vital compounds which have the potential of absorbing ultraviolet radiations, hence preventing the leaves from serious damage (Panigrahi and Vyas, 2015). The complete list of benefits of these secondary metabolites is not so clear at present, but they help a lot in explaining the relation of plants with other living organisms present in their surroundings.

This review highlights the classification of plant secondary metabolites and their uses in the daily life along with some important medicinal properties. This review mainly focuses on five important types of secondary metabolites namely alkaloids, polyphenols, saponins, terpenes/terpenoids and steroids.

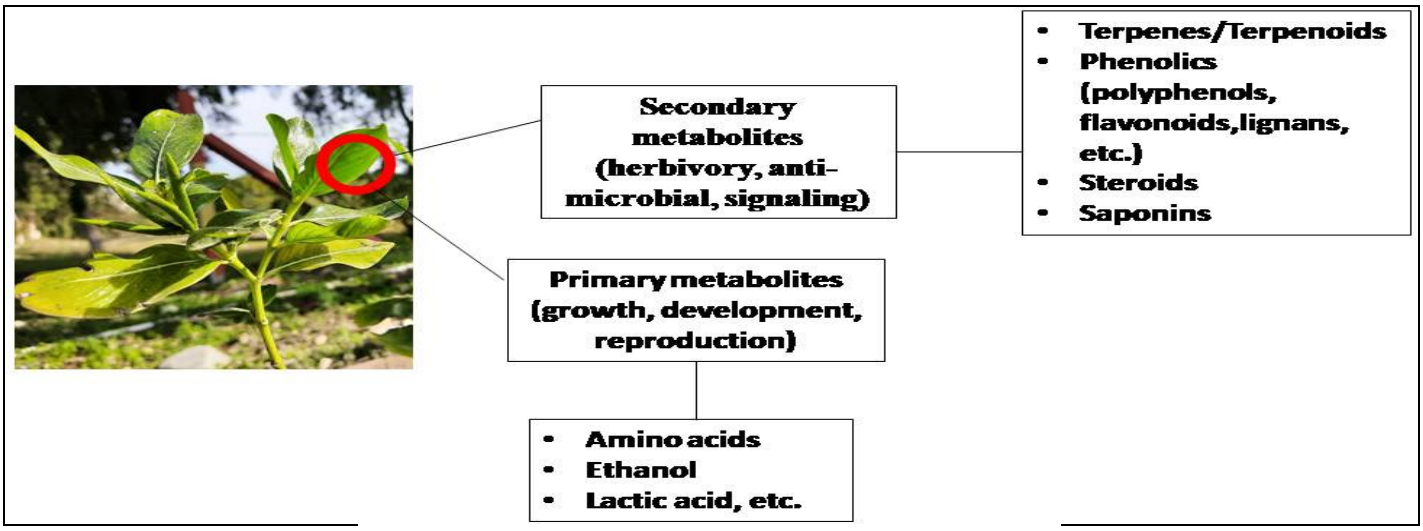

Fig. 1: Shows the classification of plant secondary metabolites.

Alkaloids

Alkaloids belong to the group of plant secondary metabolites that contains a basic nitrogen atom in the compound. In addition to the nitrogen atom alkaloids may also contain sulfur and oxygen atoms (Kabera *et al*., 2014; Chauhan *et al*., 2017). Most of the alkaloids produced by plants are toxic and are generally produced as a defense molecules against other organisms. Alkaloids are basic in nature and are mostly derived from the plant sources. Alkaloids are known to have several beneficial properties such as anti-inflammatory, anti-psychotic, anti-plasmodic activity and some alkaloid may also act as anti-neoplastic agent (Debnath *et al*., 2018; Vyas *et al*., 2016). Many studies have shown the pharmacological importance of alkaloids, one of the study on alkaloids of *Banisteriopsis caapi* showed anti-depressant and adult neurogenic activity during *in-vitro* experiments (Morales-García *et al*., 2017). Another study on alkaloid of *Opuntia polyacantha* revealed its anti-carcinogenic activity against breast cancer cell line (MCF-7) as compared to normal epithelial cell line (WRL-68) (Abdulazeem, Al-Alaq, Alrubaei, Al-Mawlah, & Alwan, 2018).

Polyphenols

Polyphenols constitutes one of the largest group of plant secondary metabolites. They are known to harbor many important biological properties some of them are anti-inflammatory, anti-cancer and antioxidant properties (Kabera *et al*., 2014, Vyas M. *et al*., 2017). Polyphenols are derived from common precursor i.e., phenylalanine or shikimic acid. These are generally categorized under four categories namely phenolic acids, stilbenes, flavonoids, lignans. Out of all these categories, flavonoids are the most studied group and many of them are responsible for giving attractive colors to fruits, flowers and leaves (Pandey & Rizvi, 2009). As described above polyphenols have many health beneficial properties, studies have shown that polyphenols are known to decrease the risk of cardiovascular diseases (Pastor *et al*., 2019). Polyphenol like epigallocatechin-3-gallate from green tea was found to improve dental health by protecting against bacterial induced dental caries (Sriram & Matthew, 2019). Moreover polyphenols were also found to have anti-ageing properties, one of such study shows the polyphenols of rosemary (*Rosmarinus officinalis*) and grapefruit (*Citrus paradisi*) protect the sun from the negative effects of the sun exposure and photoageing (Nobile *et al*., 2016). In one of the study, methoxyflavones from *Marcetia taxifolia* showed antiviral activity against Poliovirus type-1, Herpes Simplex Virus type-1 and Hepatitis B Virus (Ortega *et al*., 2019).

Saponins

The name saponin was derived from the soapwart plant whose roots were used during ancient times as a soap (Latin for soap is *sapo*). Saponins are the surface active natural glycosides with foaming characteristics. The main function of saponins in plant is antimicrobial activity and to protect plants from the attack of insects. Apart from its importance in the plant kingdom, saponins were known to have many biological functions such as hypoglycemic activity, lowering the serum cholesterol levels, anti-viral, anti-inflammatory activity and many more (Desai *et al*., 2009). Most of the population consume saponin on daily basis. Dietary source of saponins are pulses, beans, lentils, chickpeas and vegetables (Singh, Singh, Singh, & Kaur, 2017). Study on, Astragaloside IV (AS-IV) a triterpenoid saponin from an herb *Astragalus membranaceus Bunge* shown that oral administration of the saponin help in retarding the progression of Diabetes nephropathy in animal model rat (Liu *et al*., 2017, Usman *et al*., 2019). Similarly, another study revealed the anti-diabetic as well as cholesterol and triglycerides lowering potential of saponins of *Berberis vulgaris* on streptozotocin induced diabetic mice (Meliani *et al*., 2011, Kaur *et al*., 2018).

Terpenes/Terpenoids

Terpenes are the organic, chemical components of essential oils and one of the most diverse plant natural products as far as their structure is concerned. These are produced by maximum number of plants. These aromatic molecules, which are volatile in nature, have been known to contain isoprene (2-methyl-1,3-butadiene), a simple hydrocarbon molecule, as their basic structural unit, like majority of other secondary plant metabolites. Depending upon the number of isoprene units they contain, there are named as monoterpenes and sesquiterpenes. 'Terpenoids' are similar to the terpene with a slight difference; terpenoids are the derivatives of terpenes which have been denatured by oxidation, that is, they possess an extra oxygen atom in their chemical structure. These two terms are quite similar and are generally used interchangeably. There are two major roles of terpenes in every plant's life: these are not only the primary constituent of resins but they also save the flowers of the plant from predators. Terpenes are used by many industries for making beauty & health products, essential oils, and perfumes. For food additives, fragrances as well as flavouring agents, synthetic terpenes are used. For instance, the maple syrup carries around 300 different kinds of terpenes that explains the good taste of maple syrup. In case of Cannabis, terpenes can be accounted for unique taste and smell of every different strain. Terpenes are also responsible for producing a broad range of medicinal effects. Terpenes possess various proven health benefits, for instance, terpenes are highly effective in reducing inflammation, chronic pain, addiction, fungal and bacterial infections, treating epilepsy and cancer, relieving depression & anxiety, improving mood & relieving stress, enhancing focus and killing of respiratory pathogens, like, MRSA virus. Myrcene, one of the most abundant terpenes in Cannabis, accounts for inducing sleep.

Terpenes have been found to attract profitable mites that live on herbivorous insects (Kappers *et al*., 2005). The most extensively known terpene, perhaps, is rubber, that has been used widely by humans. Rubber, which is a polyterpene, comprises of many a number of repeating subunits of isoprene. Vulcanized rubber was formed by the addition of sulphur to rubber by Charles Goodyear. Other vital terpenes including menthol, camphor act as insecticides, antiallergic agents, cleaners as well as solvents. Hecogenin, another important terpene can be used as a detergent (Schwab *et al*., 2013). Various terpenes have also proved to show its antimicrobial activities (Gutiérrez-del-Río *et al*., 2018).

Steroids

Steroids are a group of low molecular weight, cholesterol derived, lipophilic compounds that are derived from a wide variety of terrestrial, marine as well as synthetic sources. It includes bile acids, a number of adrenal cortex &

gonadal hormones and a few hydrocarbons (Thao *et al*., 2015). All steroids are derived from cholesterol and therefore different classes of steroids resemble closely since All the steroids have the same basic 'perhydro-1,2-cyclopentenophenanthrene' frame; & a minute difference in this frame does result in various steroid classes. All classes of steroids along with their metabolites play very important roles in the biochemistry & physiology of living organisms within which they are present. As per their stereochemistry, the steroids are known to be a non-flat molecule with hexagonal C-rings, which generally assumes not a boat, but a chair conformation.

These steroids have many medicinal applications, although they have been often linked with the harmful effects on health. These steroids possess potential use in the promotion of fat loss as well as muscle growth, along with which it presents lesser number of side-effects. A great number of synthetic steroids have been widely used as anaesthetics, anti-cancer (Thao *et al*., 2015), anti-asthmatics (Aav *et al*., 2005), anti-hormone (Jovanovic-Santa *et al*., 2015), anti-inflammatory & contraceptive drugs (Lopez *et al*., 2014), cardiovascular agents and anti-biotics.

Table 1: Some of the pharmacologically important alkaloids and polyphenols

Secondary metabolite	Source	Type	Function	Reference
Atropine	*Atropa belladonna, Darura stramonium, Mandragora officinarum*	Alkaloid	Anti-cholinergic, anti-myopia effects	(McBrien, Stell, & Carr, 2013) (Gu *et al*., 2011)
Codeine	*Papaver somniferum*	Alkaloid	Analgesic, anti-diarrheal, antidepressant, sedative and hypnotic	(Smith, Owen, Earis, & Woodcock, 2006; Webb *et al*., 2001)
Nicotine	*Nicotiana tobaccum*	Alkaloid	Stimulant, insecticide, anti-inflammatory	(Park *et al*., 2007) (Rungsung, Ratha, Dutta, Dixit, & Hazra, 2015)
Quinine	*Cinchona succirubra, C. calisya, C. ledgeriana,*	Alkaloid	Antimalarial, analgesic, antipyretic	(Krishna *et al*., 1995)
Solanine	*Solanum tuberosum, S. lycopersiam, S. nigrum*	Alkaloid	Antifungal, sedative, anti-convulsant, Anti-carcinogenic, anti-inflammatory	(Takshak, 2018)
Tomatine	Green parts of tomato plants	Alkaloid	Antitumor, antifungal	(Kúdelová *et al*., 2013)
Berberine	*Berberis species, Hydrastis, Canadensis, Xanthorhiza simplicissima, Phellodendron amurense, Coptis chinensis, Tinospora cordifolia, Argemone mexicana and Eschscholzia californica*	Alkaloid	Anti-inflammatory, anti-bacterial/viral, anti-diabetic	(Hwang, Kwon, & Yoon, 2009)
Quercetin	Onion	Polyphenol	Reduce the risk of coronary heart disease, reduces artherosclerosis plaques	(JuŸwiak *et al*., 2005)
Resveratrol	Wine	Polyphenol	Prevents the aggregation of platelets by inhibiting cyclooxygenase1 activity	(Crescente *et al*., 2009)
Theaflavins and thearubigins	Black Tea	Polyphenol	Anti-carcinogenic and anti-clastogenic	(Bhattacharya, Mukhopadhyay, & Giri, 2011; Halder, Pramanick, Mukhopadhyay, & Giri, 2006)
Ferulic acid	Vegetables and maize bran	Polyphenol	Anti-diabetic properties	(Nankar, Prabhakar, & Doble, 2017; Narasimhan, Chinnaiyan, & Karundevi, 2015)

Conclusion

Plant secondary metabolites and their uses emerged as a large research field related to different fields such as genetics, pharmacology, functional, etc. Combining the knowledge of different fields such as botany, chemistry, pharmacology, it becomes easier to extract, characterize and validate the findings of the use of secondary metabolites as drug like compounds. This review highlights some of the important and biologically active compounds/secondary metabolites. Studies are needed to be done to explore the pharmacological potential of secondary metabolites. Validation of such bioactive compounds are needed to be done on animal models to determine its mechanism and use as a drug molecule for humans.

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