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The biological role of primary and secondary plants metabolites

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Abstract

Metabolism consists of closely coordinated series of enzyme-mediated chemical reactions that take place in the plant organism, resulting in the synthesis and use of a wide variety of molecules in the category of carbohydrates, amino acids, fatty acids, nucleotides and polymers derived from them (polysaccharides, proteins, lipids, DNA, RNA, etc.). All these processes are defined as primary metabolism and the respective compounds, which are essential for the survival of the plant, are described as primary metabolites. In addition to the primary metabolites, which play a role in maintaining the viability of the plant (proteins, carbohydrates and lipids), a number of compounds such as terpenes, steroids, anthocyanins, anthraquinones, phenols and polyphenols, which belong to the "secondary metabolism", are also synthesized. Secondary metabolites (SMs) are present only in certain species, often manifesting specificity of organ or tissue, can be identified only at a certain stage of growth and development within a species, or can be activated only during periods of stress caused by the attack. microorganisms or nutrient depletion. Their synthesis seems to have no direct significance for the synthesizing cell, but may be decisive for the development and functioning of the body as a whole. Their synthesis is not a vital part of the gene expression and developmental program, these metabolites are not simple catabolic products, have a diversified structure and can be frequently re-included in metabolic processes. The boundary between primary and secondary metabolism is uncertain, as many primary metabolism intermediates play similar roles in secondary metabolism. Some obscure amino acids are infallibly SMs, while sterols are essential structural compounds of many organisms and should therefore be considered primary metabolites.

Keywords: primary metabolism; Secondary metabolite; mechanism of action

Background

The combination of the roles of many compounds ensures a close interrelationship between primary and secondary metabolism, and the interpretation of the delimitation between these processes must be made with caution. Their conservation during the evolution of the vegetal kingdom is plausible and it can be interpreted that the SMs offer a selective advantage to the species. Species in which pollination is carried out by insects, they are attracted by color, fragrance or the presence of nectar, characteristics due to SMs. The role of pigments is also evident in the spread of fruits and seeds by birds and other animals attracted by the vivid colors of plant structures. The colorful stigmas of *Crocus sativus*, used as a food coloring, as well as the intense red color of hot peppers (*Capsicum frutescens*) and the hotness of capsaicin, have an attractive or repellent effect on animals. Plant SMs may serve as attractants to pollinators, may be chemically adapted to environmental stress, or may be an offensive, defensive, or protective chemical against microorganisms, insects, herbivores, and even other higher plants. their role as biologically, physiologically and ecologically active compounds. Examples of bioactive compounds in the SMs, such as nicotine, pyrethrins and rotenone, are used as pesticides and certain steroids and alkaloids used in the pharmaceutical industry [1]. The value of SMs used in the pharmaceutical industry can reach thousands of dollars per kg. Purified opium alkaloids (codeine and morphine) have values of 650–1250USD / kg. Essential oils (EOs) such as rose are valued at over 2000–3000USD / kg. The alkaloids extracted from *Catharanthus roseus reach* values of up to 20,000 USD / g. These prices are due to both the costly isolation methods and the small quantities that can be obtained from plant sources. The amount of vincristine, isolated from the *Catharanthus roseus* plant, is ~ 0.0003–0,0005%, requiring 500kg of leaves to produce 1g of purified vincristine, a process that takes weeks. Plants remain the only sources of extraction, as many SMs of pharmaceutical interest cannot be chemically synthesized, being complex stereostructures with many chiral centers (carbon atoms) that may be essential for biological activity [2].

Therapeutic effects and commercial value of plant-derived substances include steroidal sapogenins (digoxin and digitoxin), anticancer alkaloids (vincristine and vinblastine), belladonna alkaloids (atropine, hyoscyamine, and scopolamine), and other compounds used in the drug industry, cocaine, colchicine, opium alkaloids, phytostigmine, pilocarpine, quinine, quinidine, reserpine and d-tubocurarine, according to table 1.

No.	Class of compounds		Botanical sources	Therapeutic use
1.	Steroids	Hormones (derivatives of diosgenin, hecogenin and stigmasterol)	*Dioscorea sp., Glicine sp.*	Oral contraceptives and other steroid hormones
		Digital glycosides (digoxin, digitoxin)	*Digitalis purpurea, D. lanata*	Cardiotonics
2.	Alkaloids	Belladonna alkaloids (atropine,	*Atropa belladonna, Datura stramonium*	anticholinergic
		l – hyoscyamine, scopolamine)	*Papaver somniferum*	Analgesics
		Opium alkaloids (codeine, morphine)	*Rauwolfia serpentina*	Antihypertensives,
		Reserpine	*Catharanthus roseus*	psychotropic
		Vincristine, vinblastine	*Physostigma venenosum*	anticancer
		Physostigmine	*Pilocarpus sp.*	Cholinergic
		Pilocarpine	*Cinchona sp.*	Cholinergic
		Quinine, quinidine	*Colchicum autumnale*	Antimalarial, cardiac antiarrhythmia
		Colchicine	*Erythroxylon coca*	Gout
		d–Tubocurarină	*Strychnos sp., Chondodendron tomentosum*	Relaxant muscular

Table 1: *Classes of compounds, botanical sources and therapeutic properties*

Primary and secondary plant metabolites of economic interest have some common characteristics, most are non-proteinaceous chemical compounds, can be extracted from plant material by steam distillation, organic or aqueous solvents, and except for natural rubber biopolymers, condensed tannins and polysaccharides such as gums, pectins and starch, are low molecular weight compounds (>2000Da). Plants in the process of their phylogenetic development have adapted to certain living conditions [3].

The distribution of SMs in higher plants is in Table 2.

N0	Class of compounds		Nr. ~ of compounds	Distribution of plant chemicals	Physiological action
1.	Nitrogen compounds	Alkaloids	5.500	spread in *Angiospermae*, in roots, leaves and fruits	Most are toxic, with a bitter taste
		Amine	100	widespread in *Angiospermae*, predominates in flowers	Most have a repulsive odor. They are hallucinogenic
		Non-protein amino acids	400	They are widespread. It predominates in legume seeds	Many are toxic
		Cyanogenetic glycosides	30	Sporadic, in leaves and fruits	Poisonous (HCN)
		glucosides	75	*Cruciferae* and 10 other families	Bitter and sour taste
2.	Terpenes	monoterpenes	1000	spread in EOs	Nice smell
		Lactone sesquiterpenice	600	Predominant in *Composites*.	Some are bitter, toxic and allergic
		Diterpene	1000	Also present in other *Angiospermae*	Some are toxic
		Saponins	500	spread in latex and plant resins	They cause hemolysis of blood cells
		Limonoids	100	They are identified in over 700 plant families	Bitter taste
		Cucurbitacin	50	Present mainly in *Rutaceae*, *Meliaceae* and *Simaroubaceae*	Bitter taste, they are toxic
		Cardenolide	150	It predominates in *Cucurbitaceae*	Bitter, toxic taste

		carotenoids	400	Common in *Apocynaceae, Aschepiadaceae* and *Scrofulariaceae*	Colored substances
3.	Polyphenol	Simple phenols	200	Universal spread in leaves, often in flowers and fruits	Antimicrobial action
		flavonoids	1000	Universal spread in leaves and other tissues	Often dyes
		quinones	500	Widespread in *Ferns, Angiosperms* and *Gymnosperms*	Dyes
4.	Other compounds	polyacetylenes	650	widespread, predominant in *Rhamnaceae*	Some toxic

Table 2: *Distribution of secondary compounds in higher plants*

The geographical distribution of plants is determined by their requirements for external factors and their degree of adaptation to environmental conditions. Plants do not grow haphazardly at random; they are arranged in well-defined ecological associations and communities. While large ecological groups or associations (forests, steppes, swamps, etc.) are largely determined by climatic and edaphic factors, associations that occur in a small circle have different vegetation, in the same geographical setting, under the same influence climatic and edaphic factors. If the plants do not adapt, their living environment, growth and development is reduced and in a relatively short time, the plants will disappear. As one or more growth factors are not ensured at an appropriate level, the homogeneity of living conditions is changed and limits plant productivity [4].

If certain unfavorable conditions occur during the growth and development of plants, the plants will suffer certain disorders, depending on the potential of biochemical and physiological resistance of the respective species or varieties to harmful factors.

– The notion of physiological resistance means the acquisition of organisms to survive under the harmful influences of the environment and their ability to ensure the normal development of vital processes.

– By biochemical resistance is meant the acquisition of organisms to oppose the significant change metabolic processes under the action of unfavorable environmental factors [5-7].

Plants have the ability to adapt to the changed living environment, by modifying their enzymatic system, by biosynthesis of antibodies, inhibitors or activators, by the accumulation of osmotically active substances, etc. The term "plant" refers to ecology, higher plants, angiosperms, gymnosperms and ferns. Fungi, bacteria and viruses are called microorganisms. Algae, mosses and lichens are less exemplified because their ecological biochemistry has not been studied in detail. The presence of SMs in plants is explained by the fact that, the plants being fixed by roots in the soil, they cannot move and therefore cannot respond, directly, like animals to the action of environmental factors. SMs facilitate the actions of plants to adapt to the environment, by establishing the most complex interrelationships between plants and animals. The chemical composition of plants is the product of the interaction between the internal constitution and their living environment. Adaptation is the flexibility (ability) of the living organism to grow and develop in a changed living environment. Plants contain many SMs of metabolism compared to the animal kingdom. Some of the SMs increase the resistance of plants to the attack of microorganisms. Some compounds are toxic and are a plant protection weapon against herbivores, insects and other pests. Others act as inhibitors and stimulators of plant growth, others, such as flavonoids and carotenoids, absorb light energy and take part in the process of photosynthesis, by yielding absorbed energy to chlorophyll a and defending chlorophyll and other biologically active substances from photooxidative degradation. Some SMs determine the taste and aroma of fruits and vegetables, and ethers, esters, terpenic substances, etc., through their pleasant smell, have a role in pollinating plants. Pigments, which are by-products of metabolism, play a role in redox reactions. They determine the color of flowers, fruits, vegetables, all plant organs and are involved in the pollination process [8,9].

The food industry, the pharmaceutical industry, the cosmetics industry and the textile industry are based on the use of secondary metabolic compounds in plant organisms.

Significance, weight and value of secondary metabolites

Plants contain substances of great diversity and abundance that never end - produced by biosynthesis, or which are intermediate or final products during metabolic stages, without structural importance, without fundamental physiological roles, or even without any experimental physiological role. They have been called "secondary plant substances" and are glycosides, organic acids, secretory lipids, terpenic compounds, non-nitrogenous aromatic substances, anthocyanidins, nitrogenous SMs (amines, betaines, alkaloids, cyanide compounds), etc. In plants, these SMs are grouped into different classes based on their chemical structure and similar properties.

The name of secondary plant substances has been conventionally adapted and refers to their origin and not to their importance. SMs appear in the plant organism in the processes of formation or degradation of plastics (carbohydrates, lipids, proteins). They remain as such, depositing in the tissues or being removed [10].

SMs are intermediate and final products of metabolism. They are by-products, with little known metabolic role, with irregular distribution, but located in well-defined anatomical areas of the plant. They are important for the food and taste quality of the products but also for the technical, industrial, agricultural, pharmaceutical, etc. interest [11, 12]. Due to their industrial and therapeutic applications, many of them have been chemically researched, but little has been the subject of physiological research. In some of them, metabolic or ecological functions are found / intuited, but most of them cannot be interpreted from this point of view. Attempts have been made to reconstruct their genesis in the cell, a categorical physiological problem and undoubtedly important both for its biological mechanism and for the secretory and excretory functions of the plant, little known until now. The elucidation in phylogenetic perspective has also been tried, so they are more and more numerous and varied in the evolutionary process of the vegetal kingdom. Alkaloids, for example, are missing in *Talofite*, except for a few mushrooms; in ferns and gymnosperms they are exceptional, in rare monocotyledons and only in some dicotyledonous families do they become common. The anthocyanidins so widespread in *Phanerogamous* first appear only in a muscle, the specific variety of anthocyanins found in male individuals of *Chlamydomonas* algae is recognized. The poorest plants in secondary organic substances are cyanophyceae and chlorophylls. The enzymatic varieties of the cell increase and diversify as we move away from these groups, so that the production of SMs also increases, as soon as the qualitative diversity of the main metabolic processes increases [13-15].

Plant substances of secondary origin can be grouped into: vegetable pigments, glycosides, lignins, tannins, EOs, resins, balms, alkaloids, antibiotics, phytoncides, plant insecticides, etc. Following the process of photosynthesis in green plants accumulates a number of substances that are transported to the growing areas to increase the weight and volume of plant organs. Some of these organic substances are consumed in the process of respiration, and the rest are deposited in the reserve organs and fruits. These organic substances are divided into:

plastic organic substances; and

energetic organic substances.

Most plastics are formative (constitutive) and participate in the structural composition of cell components (nucleoproteins, lipoproteins and celluloses). Another part of plastics is deposited in various organs (reserve substances), being used in the formation of new organs (starch, hemicellulose, sucrose, simple proteins and fats). There is no separation between plastics and energy, they can be part of either group. In addition to these plant substances, the various transformations can form some substances such as: alkaloids, phytoncides, organic acids, glycosides, which perform various functions in the plant, including the defense function [16].

Of all the substances produced by photosynthesis, carbohydrates make up about 2 thirds, and the rest are other organic substances, especially those with nitrogen. In plants, carbohydrates have a carbon / oxygen / hydrogen ratio of 1/1/2 and are the basic substances of supporting tissues and all plant cells. Lipids are simple and complex fatty substances, insoluble in water and soluble in organic solvents, alcohol and ether. Lipids can be extracted from all living tissue. Glycerides-their synthesis takes place during the day, on the surface of the mitochondria in the cytoplasm of the cell and is done by transforming carbohydrates hexoses (glucose and fructose) and less carbohydrates pentose. Sterids-are esters of fatty acids with sterols. Types of sterols: systosterols (in cottonseed oil, soybeans, beans, flax, cereal seeds), stigmasterol (in soybean oil), brassicosterol (in mustard and rapeseed), spinasterol (in spinach and alfalfa seeds), ergosterol (in rye seeds, cereals, grapes, mushrooms. Cerides-together with other substances (hydrocarbons, paraffins, resins, hydroacids), turn into waxes, which are secreted by the cuticle and form a thin layer on the surface of leaves, flowers and fruit, with a protective role against excessive perspiration and harmful agents. Complex lipids (lipoids) - are found in plants in the proportion of 1-2% in the form of glycerol-phospholipids, sphingolipids, glycolipids, gluco-sulfolipids and lipoproteins. Synthesis, transformation and deposition of nitrogenous substances [17].

Amino acids - are the simplest organic substances with nitrogen and can form directly in the process of photosynthesis (in light the synthesis of proteins in plants takes place in just 3-5 minutes). Proteins in the fundamental substances of the cellular protoplasm have in their composition a weight of more than 50%, and in the vegetal organs these proteins accumulate as reserve substances in seeds, especially in legumes, flax, beans, peas, soybeans or lupine. Protein is also deposited in wheat and corn caryopsis. Among the various protein substances in plants are also found: albumin, globulin (in wheat caryopsis), prolamins (in corn zein). Among the heteroproteins, important are the chromoproteins, which include: chlorophyll, carotenoproteins and enzymes, cytochromes, cytochrome oxidase, peroxidases and catalases. Transport of organic substances through the xylem - the organic substances used in the roots move to the aerial organs. Transport of organic substances by phloem - organic substances are synthesized in leaves, from where they circulate through all living tissues. The transport of organic substances in plants is done through the wooden leading vessels (xylem) and the Liberian leading vessels (phloem) [18]. Biologically important are:

Plant pigments are coloring substances synthesized by plants, which give color to their tissues, chlorophyll (chlorophyll) give green color to leaves, young fruits, shoots, etc. Chemically, two green pigments were isolated from chlorophyll extract: chlorophyll a and chlorophyll b, as well as two yellow pigments: carotene (carotene) and xanthophyll, both called carotenoids or carotenoids. Carotene ($C_{40}H_{56}$), also called provitamin A, is found in all species and has a role in maintaining and strengthening health. Xanthophyll ($C_{40}H_{56}O_2$) differs from carotene in that it has two additional oxygen atoms. Xanthophyll is found in leaves and fruits, along with chlorophyll and carotene. Lycopene is an isomer of carotene, which gives the fruit a red-orange color. Anthocyanins are red, pink, purple, or blue pigments that form in the presence of light. They are found in the skin, pulp and juice of some species and varieties of fruit, in the petals of the fruit, sometimes even in the leaves and bark of the shoots. The red pulp is found in strawberries, cherries, some varieties of cherries, plums, peaches, apples, etc. [19]

Anthocyanins have tannic, protein precipitating properties, which explains their hemostatic and healing action, contributes to the stabilization of vitamin C. Pigmented fruits in red are more juicy, sweet, fragrant, rich in vitamins and have a longer shelf life. with weakly pigmented or rust. EOs - accumulate on the leaves or branches of some plants: mint, chrysanthemum, lavender and green nuts. EOs are in the form of volatile refrigerant droplets. They are found in the cells of the petals of *Rosa canina* (rosehip), in the secretory brushes from the plants of the Labiatae family. The walls of the cells in which the EOs are found are submerged, thus being impermeable. The EOs are stored in membrane-free intracellular vesicles or in the case of secretory hairs, after their elaboration in the cytoplasm they cross the wall and accumulate in a subcuticular vesicle from where they evaporate into the atmosphere. These substances are important for their antimicrobial and antiseptic effect.

The smells of flowers and fruits are due to simple organic substances: ethers, esters, unsaturated alcohols, etc., which can also be obtained in the laboratory. Flowers, leaves, fruits and fragrant roots owe their characteristic scent to volatile organic substances, called volatile oils, EOs (essences). In some plants the root is fragrant, in others the flowers and leaves. Due to their pleasant smell, EOs are used in the perfume industry [20].

Not every odor is a perfume. For a substance to be a perfume, it must meet two conditions: it must be volatile at normal temperatures, it must be able to spread easily in the air, and it must produce a pleasant sensation on the senses. Resins are found in coniferous and deciduous species, forming various cells in the stem and leaves. Resins come from the oxidation and polymerization of EOs. They are viscous substances, with a complex composition, being a mixture of terpenes and resin acids. They are found in the cytoplasm in the form of fine, shiny droplets that diffuse into intercellular spaces or are stored in cavities and resin channels. Resins, excreted by plants, occur in woody tissue, mixed with small amounts of EOs. It is derived from oils, and by oxidation it combines and forms oleoresins. Resins are solid or semi-solid substances, soluble in organic solvents. Boiling at high temperatures (above 30ºC), they are not distillable, they do not have fixed melting points (they suffer from softening). Chemically, resins consist of resin acids (abietic acid) and their derivatives, polycyclic substances (acidic character). They have narcotic, purgative, expectorant, deworming properties. It accumulates in isolated cells (idioblasts), in epidermal cells, hairs, pockets and secretory channels (sacs and incense) [21].

Balms are liquid or semi-solid resins with a high content of EOs (up to 40%). In contact with air, as well as resins, balms solidify because some of the EOs in their constitution volatilize. Lignans are also resins in which substances related to the structural elements of lignins (monomers, dimers, etc.) predominate. Guaiac resin containing guajaritic acid is found in *Guaiacum officinalis* and is rich in lignans. Resins and EOs are a means of protecting plants from parasites. Their smell can attract some insects, favoring pollination. Resins that are deposited on various lesions of the plant organism have a protective, insulating and healing role. EOs are also important due to their practical use in perfumery, in the pharmaceutical industry, in the food industry, etc. Resins are used in the textile industry, in the preparation of varnishes and paints, in the pharmaceutical industry, etc. Alkaloids are complex nitrogenous organic substances, produced only by the plant organism, which have a more or less important alkaline reaction. They are the end products of nitrogen metabolism. ~ 5000 different natural alkaloids are known. Alkaloids can be found in leaves (tea, coca), seeds (coffee), roots and bark, spermoderm (cranberries), fruit "bark" (poppy), secretory channels, latex, etc. Alkaloids have heterocyclic structures. Due to the nitrogen in the molecule, it is basic. They are water insoluble and soluble in organic solvents. Reacts with mineral acids and forms soluble salts. In plants they are found in the form of salts of oxalic, citric, malic, fumaric, etc. acids [22].

It has physiological effects on humans and animals. Alkaloids are used therapeutically as narcotics and sedatives. Some alkaloids are poisons that have the ability to paralyze the nervous system. Alkaloids are thought to be a means of protecting plants from insects. Other alkaloids, such as nicotine, play a role in oxidative redox processes. Alkaloid-producing plants are dicotyledons, and to a lesser extent monocotyledons and cryptogams. A plant contains several alkaloids. The alkaloid content depends on the age of the plant, region, climate and season. Algae and muscles have no alkaloids, are rare in fungi (ergotamine), pteridophytes (nicotine in *Equisetum, Lycopodium* spores) and gymnosperms (ephedrine in *Ephedra*). In angiosperms, there are families famous for their alkaloid content: *Solanaceae* (solanine, nicotine, hyoscyamine, atropine, etc.), *Rubiaceae* (caffeine, ernetin, quinine), *Papaveraceae* (morphine, papaverine, codeine, narseine, etc.). These active ingredients are found in cellular juice in the form of bases, but especially as salts of common organic acids such as citric acid, malic acid, oxalic acid, succinic acid, tannic acid, tartaric acid or other acids such as aconic acid, caffeic acid, chelidonic acid, quinic acid, chlorogenic acid, meconic acid, synaptic acid, veratric acid, etc. [23].

Plant antibiotics (phytoncides). They are substances with antibiotic properties synthesized by plants. Phytoncides have a lower antibiotic action compared to antibiotics of microbial origin. Some phytoncides also have insecticidal properties compared to insects, worms, rodents, etc. We know over 50 phytoncides extracted from different plants, of which the most important are: allicin, dihydroallin, benzoic acid, allyl-senevol, etc.

Allicin is a volatile antibiotic extracted from garlic, with destructive action on the diphtheria bacillus, cholera, staphylococci, etc. Dihydroaline is an antibiotic extracted from onions. Benzoic acid, p-hydroxyl-benzoic acid, vanillic acid, caffeic acid, ferulic acid, etc., are spread in higher plants (carrots), have bacteriostatic, bactericidal and anti-hormonal action. They prevent gibberellin biosynthesis. Allyl-senevolul, is extracted from mustard, horseradish, radish, etc. Some alkaloids and tannins have phytoncidal properties. Medicinal plants, flowers, roots and tubers of some plants (legumes, orchids) are a source of plant antibiotics [24].

Plant insecticides. Some higher plants can synthesize certain substances with insecticidal action, which will exert a defense action against insects, worms, rodents, etc. Chemically, plant insecticides have different structures such as: unsaturated ketoalcohols (pyrethrolone), unsaturated cyclic esters (pyrethrin and cinerine), benzo-pyranes (rotenone, which is toxic to animals), glycosides (red onion scylrosis), senile (senile phenyl). –Ethylene, extracted from beets, strong insecticide, of the same grade as aldrin and chlordane), unsaturated branched amides. Higher plants can synthesize defense substances with bacteriostatic, bactericidal, fungicidal or insecticidal properties. In the flowers of *Chrysantheum cinerariaefolium, Peonia albiflora, Pyrethrum carneum* etc. unsaturated cyclic esters are found. By hydrolysis an unsaturated ketoalcohol, pyrethrolone or cinerolone and a monocarboxylic / dicarboxylic cyclopropane acid are formed. In legumes of the genera *Derris, Jochocarpus, Tephhrosia, Millelia,* etc., there are insecticides from the group of rotenoids, which have a benzopyranic or benzopyronic nucleus in the molecule. They are toxic not only to insects but also to other lower animals and fish. The presence of phytoncides in plants can be noticed if a berry and a stick, of the same thickness as the tree, are planted in a ruderal soil. The stick degrades in a short time, under the action of microorganisms in the soil, while the tree protects itself from the action of microorganisms, through the phytoncides it contains. As the stick degrades, the tree grows and develops under the action of environmental factors. Lignins are macromolecular substances that accompany cellulose in various organs and tissues of plants. They are substances distributed in the vegetable kingdom, occupying the second place after cellulose [25].

They are found in the wood of different plant species in a proportion of 21–30% of the dry matter. Flax and hemp fiber are low in lignin, and jute fiber contains 19% lignin. Lignins are ternary substances, consisting of C, H and O, of an aromatic nature. Characteristic is the presence of methoxyl and hydroxyl groups in the molecule. The basic constituents of lignins are aromatic alcohols derived from phenylpropane: coniferyl alcohol, hydroxyconiferyl alcohol and synaptic alcohol. Glycosides are two-component substances, a carbohydrate component and a non-carbohydrate component called aglycone. The carbohydrate component binds to the aglycone through a glycosidic bond via the semiacetal hydroxyl. The carbohydrate component may be monoglucide, diglucide or an oligoglucide. Glucose or glucose-containing oligoglycides predominate. Aglycone can belong to extremely different classes of substances such as alcohols, phenols, sterols, thioalcohols, hydroxyquinones, pigments, nitrogenous substances, etc. Glycosides are widespread in the plant kingdom. They are found both in higher plants, in leaves, flowers, fruits, seeds, roots, wood, etc., and in lower ones. They are solid, crystalline, colorless or colored substances (according to the type of aglycone), with a bitter taste, some have a specific aroma. Glycosides have optical activity. Most are soluble in water, alcohol, acetone and insoluble in ether. They do not show the mutarotation phenomenon and do not have reducing properties. It is easily hydrolyzed in an acidic, basic medium or under the action of enzymes. Glycosides have a physiological action on animal organisms (curative or harmful) and have been used since ancient times as medicines or poisons. Some glycosides are harmless to plants that store toxic aglycones [26].

Vegetable tannins are substances known for their many practical applications, in traditional medicine and in the tanning industry. Ancient North American tribes used decoctions and poultices made from the roots of some plants (high in tannins, such as the Canadian water lily *Nuphar variegatum*) to treat sore throats, leukorrhea, colds, wounds, internal pains, or other skin infections. The tanning of the skin with vegetable tannins has been known since antiquity and it was made using the bark of different species of trees (oak). The establishment of their molecular structure allowed the establishment of some differences, in terms of practical utility, between the different types of tannins. Galotanins and elagotanins (both belonging to the class of hydrolyzable tannins) have more practical applications than condensed tannins. Glucosinolates are another group of plant phytochemicals that are part of the glycosidic compounds that contain sulfur and nitrogen (derived from an amino acid and a molecule of glucose). They appear as SMs of plants of the Brassicaceae family, and after harvest they are transformed under the influence of enzymes (myrosinase) into isothiocyanates (contain sulfur) and indoles (do not contain sulfur). Glucosinolates are present in cabbage and cauliflower and less so in broccoli and Brussels sprouts. Chemically each glucosinolate has a central carbon atom linked by double bonds to a sulfur atom and a nitrogen atom (R – N = C = S). ~ 120 glucosinolates synthesized from plant amino acids are known, divided into two groups: aliphatic glucosinolates, derived from methionine (glucorafarin); and aromatic (or indole) glucosinates, derived from tryptophan or phenylalanine (glucobrasicin) [27].

Mustard plants contain enzymes (myrosinase, stored separately in plant cells) which, in the presence of water, after breaking the cells, break down the glucose molecule from the glucosinolate complex, quickly transforming this chemical complex into thiocyanate, which gives the mustard its characteristic taste. Plants that produce large amounts of glucosinolates are those that are used to prevent tumor growth; Broccoli has a high potential for producing sulforaphane.

Concluding Remarks and Future Perspectives

Plants are hosts for a wide range of pathogens, which induce various diseases and significant production losses. Pathogens can damage any part of the plant causing defoliation, chlorosis, stunting, photosynthesis cessation, damage, distortion, necrosis and plant death. Although plants do not have a circulating antibody system, characteristic of the animal kingdom, they have evolved a defense system during their evolution, able to withstand the attack of potential invaders. For plants, several types of resistance are characteristic, which depends on: the species, variety and population of which the host plant belongs; the species and race or population of the parasite; abiotic or biotic environmental factors. Depending on the functional criteria, the resistance of the host plant to the attack of pathogens may be nonspecific and specific, or a particular type of response to the invasion of pathogens - systemic resistance.

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