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Biological Functions and Anti-nutritional Effects of Phytochemicals in Living System

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Abstract: *Phytochemicals are chemical compounds produced by plants which help in the overall maintenance of the health of an organism but are not essential nutrients. This is because in excess some phytochemicals act by decreasing nutrient intake. These chemicals occur naturally in fruits, vegetables, legumes, nuts and whole grains, and perform biological functions by acting as antioxidants, physiological agents, antimicrobial agents and numerous other functions depending on the type of phytochemical present. Scientists estimate that there are over 10,000 of different phytochemicals having the potential to affect diseases such as cancer, stroke, metabolic syndromes etc. Although only a small fraction of these phytochemicals have been studied closely and this is why nine of the common phytochemicals; flavonoids, cardiac glycosides, alkaloids, phytate, haemaglutinin, saponins, tannins, oxalate and phenols were reviewed to unveil its biological roles and its anti-nutritional instincts.*

Keywords: *Anti-microbial agents, Anti-nutrients, anti-oxidants, diseases, phytochemicals.*

I. Introduction

Phytochemicals are plant derived chemicals which are beneficial to human health and disease prevention [1]. The term is generally used to refer to those chemicals that may have biological significance, for example antioxidants, but are not established as essential nutrients which when in excess could be detrimental. It is pertinent to state that in as much as they help to strengthen the body defense mechanism serving mostly as antioxidants, moderate consumption is highly recommended so that they will not serve as anti-nutrient to the body [2]. Scientists estimate that there are thousands of known phytochemicals [3] having the potential to affect diseases such as cancer, stroke and metabolic syndrome and those caused by microorganisms [4]. Potential phytochemicals in freshly harvested plant foods are often destroyed or removed by local and modern processing techniques. For this reason, industrially processed foods likely contain fewer phytochemicals and may thus be less beneficial than unprocessed foods. Absence or deficiency of phytochemicals in processed foods may contribute to increased risk of preventable diseases [5, 6].

Ibrahim and Fagbohun [7], stated that the most important of these bioactive compounds of plants are alkaloids, flavonoids, tannins, and phenolic compounds. This is not to say that others are not important but the mentioned few occur commonly in plants, hence the review will focus on nine phytochemicals; flavonoids, cardiac glycosides, alkaloids, phytate, haemaglutinin, saponins, tannins, oxalate, and phenols.

1.1 General Functions of Phytochemicals

Most phytochemicals are known to posses many properties which makes them vital to both plants and animals. Some of these properties are;

(a) Anti-oxidant property: Some phytochemicals are known to protect cells against oxidative damage and help lower the risk of developing cancer.
(b) Anti-microbial properties: Many phytochemical protect the body from microbial activities. For instance, allicin which is found in both onion and garlic blocks and eliminates certain toxins that are from bacteria [8].
(c) Physiological activities: Some phytochemicals bind physiologically to cell walls interfering with the ability of pathogens to bind to cell receptors. Proanthocyanidins are responsible for the anti-adhension properties of cranberry [9]. For instance, the consumption of cranberries will help reduce the risk of urinary tract infections and will improve dental health [9].
(d) In addition to its anti-oxidants activity, phytochemicals helps stimulate the immune system, modulate the detoxification of enzymes and steroid hormone concentration. They also help decrease platelet aggregation, modulate hormone metabolism, cholesterol mechanism, blood pressure reduction, as well potent against some viruses and bacteria.

1.2 Types of Phytochemicals

1.2.1 Flavonoids: Flavonoids (or bioflavonoids) (Fig 1.) are a class of plant secondary metabolites. Its name came from the Latin word flavus meaning yellow; their colour in nature. Flavonoids were referred to as Vitamin

P (probably because of the effect they had on the permeability of vascular capillaries) from the mid-1930s to early 50s, but the term has since fallen out of use [10]. Flavonoids (specifically flavanoids such as the catechins) are "the most common group of polyphenolic compounds in the human diet and are found ubiquitously in plants" [11]. Flavonols, the original bioflavonoids such as quercetin, are also found ubiquitously, but in lesser quantities.

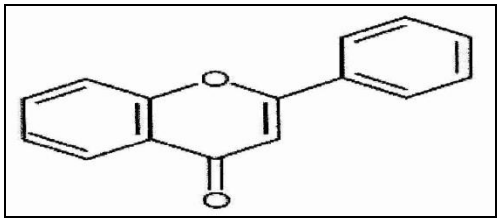

Figure 1: Molecular Structure of the Flavone backbone.

1.2.1.1 Biological Function of Flavonoids

Flavonoids have protective effects including anti-inflammatory, anti-oxidant, anti-viral, and anti-carcinogenic properties. They are generally found in a variety of foods, such as oranges, tangerines, berries, apples and onions [12]. The widespread distribution of flavonoids, their variety and their relatively low toxicity compared to other active plant compounds (for instance alkaloids) mean that many animals, including humans, ingest significant quantities in their diet. Preliminary research indicates that flavonoids may modify allergens, viruses, and carcinogens, and so may be biological "response modifiers". In vitro studies show that flavonoids also have anti-allergic, anti-inflammatory, anti-microbial [13, 14], anti-cancer and anti-diarrheal activities [15]. In vitro, flavonoids have antiviral activity against several viruses, among them poliovirus [16].

1.2.1.2 Anti-Nutritional Effects of Flavonoids

At very high concentration, flavonoids chelate metals such as iron and zinc and reduce the absorption of these nutrients. They also inhibit digestive enzymes and may also precipitate proteins. In one experiment, flavonoids were found to be strong topoisomerase inhibitors and induce DNA mutations in the MLL gene, which are common findings in neonatal acute leukemia [17, 18]. The DNA changes were increased by treatment with flavonoids in cultured blood stem cells [19]. In one study, a high flavonoid-content diet in mothers seemed to increase risk of MLL+ acute myeloid leukemia in neonates. This result was not statistically significant though, and when the data on all types of leukemia in the study were taken together, a beneficial effect of the high-flavonoid diet was seen [20, 21].

1.2.2 Cardiac Glycosides

Cardiac glycosides (Fig. 2) are found as secondary metabolites in several plants, but also in some animals, such as the milkweed butterflies. They are drugs used in the treatment of congestive heart failure and cardiac arrhythmia though the dosage must be controlled carefully, since the therapeutic dose is close to the toxic dose [22].

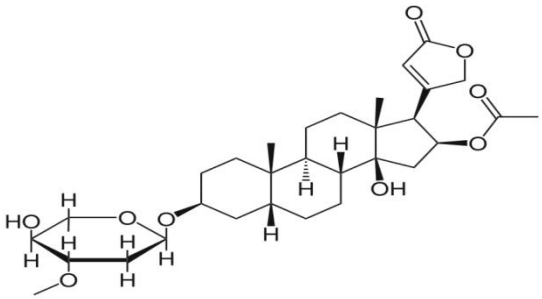

Figure 2. The chemical structure of oleandrin, toxic cardiac glycosides.

1.2.2.1 Biological Function of Cardiac Glycosides

Drugs like ouabain and digoxin are the example of cardiac glycosides. Digoxin found in the foxglove plant is used clinically, while ouabain is used only experimentally due to its extremely high effectiveness [23]. Cardiac glycosides are known to work by inhibiting the Na^+/K^+ pump. This causes an increase in the level of sodium ions in the myocytes, which then lead to a rise in the level of calcium ions. This inhibition increases the amount of calcium ions available for contraction of the heart muscle, which improves cardiac output and reduces distention of the heart; thus, they are used in the treatment of congestive heart failure and cardiac arrhythmia.

1.2.2.2 Anti-Nutritional Effects of Cardiac Glycosides

Among the chemical compounds that protect certain plants from insects or other animals that might feed on them are the cardenolides, or the cardiac glycosides. These substances have a highly toxic effect on the vertebrate heart and also activate the nerve centre in the brain that causes vomiting. However, if SR calcium stores become too high, some ions are released spontaneously through SR ryanodine receptors. This effect leads initially to bigeminy: regular ectopic beats following each ventricular contraction. If higher glycoside doses are given, rhythm is lost and ventricular tachycardia ensues, followed by fibrillation.

1.2.3 Alkaloids

Alkaloids (Fig. 3) are a group of naturally occurring chemical compounds that contain mostly basic nitrogen atoms. There are other related groups of compounds with neutral and even weakly acidic properties [24, 25].

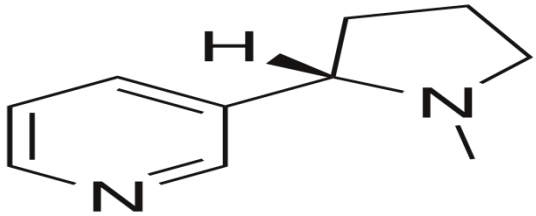

Figure 3. The nicotine molecule contains both pyridine (left) and pyrrolidine rings (right).

1.2.3.1 Biological Function of Alkaloids

Alkaloids are readily available in leaves, bark, roots or seeds of plants with diverse biological functions. Some alkaloids stimulate the nervous systems; others can cause paralysis, elevate blood pressure or lower it. Certain alkaloids act as pain relievers, tranquilizers etc (TABLE 1). Although alkaloids act on a diversity of metabolic systems in humans and other animals, they almost uniformly invoke a bitter taste [26].

Table 1: The Medicinal Value of Some Alkaloids

ALKALOIDS	FUNCTION
Atropine	Anti-cholinergic
Caffeine	Stimulant, diuretic
Codeine	Cough Medicine, analgesic
Colchicine	Remedy for gout
Emetine	Antiprotozoal Agent
Ergot alkaloids	Vasodilator
Morphine	Analgesic
Nicotine	Stimulant, receptor agonist
Quinidine	Antiarrhythmic
Quinine	Antimalarial
Tubocurarine	Muscle relaxant
Vinblastine	Antitumor
Vincamine	Vasodilating, antihypertensive

1.2.3.2 Anti-Nutritional Effects of Alkaloids

High level of alkaloids exerts toxicity and adverse effects to humans, especially in physiological and neurological activities. For instance, consumption of tropane alkaloids will cause rapid heartbeat, paralysis and in fatal case, lead to death. Uptake of high dose of tryptamine alkaloids will lead to staggering gate and death. However, doses differentiate between toxicity and pharmaceutical effects of alkaloids. As an illustration, lower dose of alkaloids mediate important pharmacological activities, such as analgesic, reducing blood pressure, killing tumour cells, stimulating circulation and respiration [27]. Alkaloids like muscarine found in toxic variety of mushroom may produce nausea, vomiting, diarrhea and in large quantity can cause acute necrosis of liver and death [28].

1.2.4 Phytate

Phytic acid (known as inositol hexakisphosphate (IP6) (Fig. 4), or phytate when in salt form, discovered in 1903, is the principal storage form of phosphorus in many plant tissues, especially bran and seeds. Phytate is not digestible to humans or nonruminant animals, this is because these animals lack the digestive enzyme phytase required to remove phosphate from the inositol in the phytate molecule. On the other hand, ruminants readily digest phytate because of the phytase produced by rumen microorganisms [29]. So it is not a source of either inositol or phosphate if eaten directly by human. Moreover, phytic acid chelates and thus makes

unabsorbable certain important minor minerals such as zinc and iron, and to a lesser extent, also macro minerals such as calcium and magnesium; phytin refers specifically to the calcium or magnesium salt form of phytic acid. Catabolites of phytic acid are called lower inositol polyphosphates. Examples are inositol penta- (IP5), tetra- (IP4), and triphosphate (IP3).

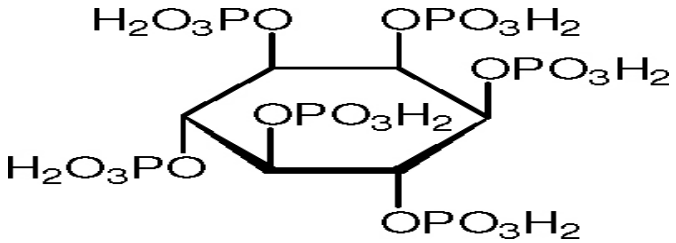

Figure 4. Molecular Structure of Phytic acid, ($C_6H_{18}O_{24}P_6$.).

1.2.4.1 Biological Functions of Phytic Acid

Liu et al., [30] reported the anti-cancer property of phytic acid and show a protective action in carcinogenesis. Phytic acid acts as anti-cancer agent against colon, soft tissues, metastatic lung cancer and mammary cancer. The presence of phytic acid in dietary sources is believed as a potential antioxidant [27]. It reduces iron-induced oxidative injury and reverses stimulation colorectal tumorigenesis (tumour formation) due to its mineral chelating potential. The antioxidant property of phytic acid can be used as a unique and versatile food preservative. Besides, the addition of phytic acid into fruits, vegetables, cheese, noodles, soy sauces, juices, bread, alcoholic beverages, meats, fishmeal pastes and canned seafood increase nutritive value, prolong shelf life and prevent discolouration of food [31].

Phytic acid was found to reduce blood glucose and possesses health benefits to diabetic patients. The anti-nutrients concentration of phytic acid reducing the rate of starch digestion and slowing the gastric emptying, in turn lowers blood glucose. Dost and Tokul, [31] reported that phytic acid can prevent kidney stone formation.

1.2.4.2 Anti-Nutritional Effects of Phytic Acid

Excessive amounts of phytic acid in the diet will form insoluble complexes with multi-charged metals [32], such as copper (II), zinc (II), calcium (II) and iron (III). This results a deficit in the absorption of some dietary minerals [33], and leads to mineral deficiencies. Phytic acid was reported to interact with other compounds: formation of ternary complexes of phytic acid with protein and carbohydrate (starch) will reduce their bioavailability and digestion [27]. For instance, the formation of phytic acid – carbohydrate complex influences digestion rate of starch [34]. Phytic acid – protein complex will inhibit digestive enzymes. Although home food preparation methods can degrade phytic acid. Simply cooking the food will reduce the phytic acid to some degree. More effective methods are soaking in an acid medium, lactic acid fermentation, and sprouting.

1.2.5 Haemagglutinin

Haemagglutinin is any substance that causes the agglutination of the red blood cell. Phytohaemagglutinin (PHA) is a lectin found in plants, especially in legumes. A notable example is ricin, an extremely toxic hemagglutinin from seeds of the castor plant (*Ricinus communis*).

1.2.5.1 Biological Function of Plant Haemaglutinin

Most lectins do not possess enzymatic activity and are not produced naturally by the immune system. Lectins occur ubiquitously in nature. They may bind to a soluble carbohydrate or to a carbohydrate moiety that is a part of a glycoprotein or glycolipid. They typically agglutinate certain animal cells and/or precipitate glycoconjugates. Biological functions of haemaglutinin are summarized as follows:

(a) Functions in Animals: Lectins serve many different biological functions in animals, they play a role in the biological recognition phenomena involving cells and proteins [35, 36]. They play a role in cell regulation and adhesion, glycoprotein synthesis and the control of protein levels in the blood. They may also bind soluble extracellular and intercellular glycoproteins. Some lectins are found on the surface of mammalian liver cells that specifically recognize galactose residues. It is believed that these cell-surface receptors are responsible for the removal of certain glycoproteins from the circulatory system.

(b) Functions in Plants: The function of lectins in plants (legume lectin) is still not clear. Several plant lectins have been found to recognise non-carbohydrate ligands that are primarily hydrophobic in nature, including adenine, auxins, cytokinin, and indole acetic acid, as well as water-soluble porphyrins. It has been suggested that these interactions may be physiologically relevant, since some of these molecules function as phytohormones [37] are another major family of protein ANCs, which are specific sugar-binding proteins

exhibiting reversible carbohydrate-binding activities. Lectins are similar to antibodies in their ability to agglutinate red blood cells; however, lectins are not the product of immune system.

(c) Use in science, medicine and technology: Use in medicine and medical research: Purified lectins are important in a clinical setting because they are used for blood typing [38]. Some of the glycolipids and glycoproteins on an individual's red blood cells can be identified by lectins [38].

1.2.5.2 Anti-Nutritional Effects of Plant Haemaglutin

Foods with high concentrations of lectins, such as beans, cereal grains, seeds, nuts, and potatoes, may be harmful if consumed in excess in uncooked or improperly cooked form. Adverse effects may include nutritional deficiencies, and immune (allergic) reactions. Possibly, most effects of lectins are due to gastrointestinal distress through interaction of the lectins with the gut epithelial cells. A recent in vitro study has suggested that the mechanism of lectin damage may occur by interfering with the repair of already-damaged epithelial cells [39]. Lectin may cause leptin resistance. Such leptin resistance may translate into diseases, notably it could be responsible for obesity in humans who have high levels of leptin [40].

1.2.6 Saponins

Saponins are terpene glycosides. They are one of many secondary metabolites found in natural sources, with saponins found in particular abundance in various plant species. More specifically, they are amphipathic glycosides (Fig. 5) grouped in terms of phenomenology, by the soap-like foaming they produce when shaken in aqueous solutions, and, in terms of structure, by their composition of one or more hydrophilic glycoside moieties combined with a lipophilic triterpene derivative [41].

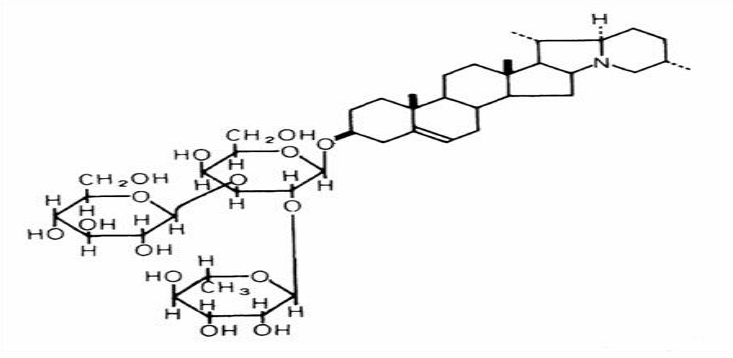

Figure 5. Chemical structure of the saponin solanine.

1.2.6.1 Biological Functions of Saponins

Research sources disclosed that saponins exert various biological benefits, such as anti-inflammatory, anti-diabetic, anti-HIV, anti-atherosclerotic and serve as protective functions like gastro-protective, hepatoprotective and hypolipidemic [42, 43]. Besides, saponins are effective in maintaining liver function, lowering blood cholesterol, preventing peptic ulcer, osteoporosis as well as platelet agglutination [44]. The beneficial effects of saponins have been applied commercially in drugs and medicines, emulsifiers, adjuvants, taste modifiers, sweeteners and precursors of hormone synthesis [41].

Saponins are used widely for their effects on ammonia emissions in animal feeding [45]. The mode of action seems to be an inhibition of the urease enzyme, which splits up excreted urea in feces into ammonia and carbon dioxide. Animal trials have shown that a reduced ammonia level in farming operations causes fewer damages to the respiratory tract of animals, and may help to make them less vulnerable to diseases.

1.2.6.2 Anti-Nutritional Effects of Saponins

Dietary saponins are highly toxic to cold-blooded animals due to its haemolytic property, in which it ruptures erythrocytes and release haemoglobin. Saponins were found to reduce nutrient utilization and conversion efficiency as in ruminants [46, 47]. In case of monogastric animals, saponins acts as growth inhibitor and reduce their feed intake due to the bitterness and throat-irritating activity of saponins. Dietary saponins from different plants were found to reduce weight gain in salmonid fish [48], reduce fertility [49], and cause ruminant bloat and photosensitization [46]. It affects protein digestibility by inhibiting various digestive enzymes such as trypsin and chymotrypsin [50].

1.2.7 Tannins

A tannin (Fig. 6) (also known as vegetable tannin, natural organic tannins or sometimes tannoid, i.e. a type of biomolecule, as opposed to modern synthetic tannin) is an astringent, bitter plant polyphenolic

compound that binds to and precipitates proteins and various other organic compounds including amino acids and alkaloids.

Tannins are usually subdivided into two groups: hydrolyzable tannins (HT) and proanthocyanidins (PA). Hydrolyzable tannins are gallic acid and ellagic acid esters of core molecules that consist of polyols such as sugars and phenolics such as catechin. Hydrolyzable tannins are more susceptible to enzymatic and non-enzymatic hydrolysis than PA, and usually are more soluble in water. Hydrolyzable tannins are further classified according to the products of hydrolysis; gallotannins yield gallic acid and glucose and ellagitannins yield ellagic acid and glucose [51]. Proanthocyanidins are polymers of flavan-3-01s linked through an interflavan carbon bond that is not susceptible to hydrolysis. Proanthocyanidins are more commonly referred to as condensed tannins. Hydrolyzable tannins also undergo condensation reactions.

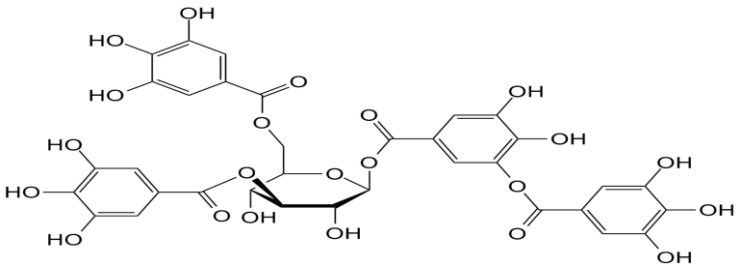

Figure 6. Tannic acid, a type of tannin.

1.2.7.1 Biological Function of Tannins

Tannins have shown potential antiviral [52], antibacterial [53] and antiparasitic effects [54]. It was also reported that certain tannin are able to inhibit HIV replication selectivity and is also used as diuretic [51]. Plant tannin has been recognized for their pharmacological properties and is known to make trees and shrubs a difficult meal for many caterpillars [51]. The tannin compounds are widely distributed in many species of plants, where they play a role in protection from predation, and perhaps also as pesticides, and in plant growth regulation [55]. The astringency from the tannins is what causes the dry and puckery feeling in the mouth following the consumption of unripened fruit or red wine [56]. Likewise, the destruction or modification of tannins with time plays an important role in the ripening of fruit and the aging of wine.

1.2.7.2 Anti-Nutritional Effects of Tannins

(a) Intake: Tannins may reduce intake of forage legumes by decreasing palatability or by negatively affecting digestion. Astringency is the sensation caused by the formation of complexes between tannins and salivary glycoproteins. Astringency may increase salivation and decrease palatability. Waghorn et al., [57] suggested that decreased ruminal turnover and rate of digestion was more important than palatability in reducing intake of sheep fed pure diets of *Lotus pedunculatus* in comparison to sheep fed *L. pedunculatus* along with polyethylene glycol (PEG) [58].

(b) Growth: Rate of gain for growing animals reflects total intake and availability of nutrients in the diet. Low growth rates because of low total intake were observed in animals eating fruits of *A. sieberiana* and *A. nilotica*, which contained high levels of tannins [59]. Low total intake and low growth rates were also observed in animals eating *A. sieberiana* pods and leaves of *A. cyanophylla* [58]. The negative effect of tannins on growth rate was caused by a combination of reduced intake and low true digestibility of protein.

(c) Digestion of Fiber Fraction: Tannins may reduce cell wall digestibility by binding bacterial enzymes and forming indigestible complexes with cell wall carbohydrates [58]. Digestibility of organic matter and fiber fractions was lowest for sheep fed A. cyanophylla, the supplement with the highest content of PA and soluble phenolics. Digestibility of ADL was negative for all three acacias in this trial [58].

1.2.8 Oxalate

Oxalate (IUPAC: ethanedioate) is the dianion with the formula $C_2O_4^{2-}$, also written $(COO)_2^{2-}$ (Fig. 7). Oxalate also forms coordination compounds where it is sometimes abbreviated as ox. Many metal ions form insoluble precipitates with oxalate, a prominent example being calcium oxalate, the primary constituent of the most common kind of kidney stones. Oxalate occurs in many plants, where it is synthesized via the incomplete oxidation of carbohydrates. Oxalate-rich plants include fat hen ("lamb's quarters"), sorrel, and several Oxalis species. The root and/or leaves of rhubarb and buckwheat are high in oxalic acid [60].

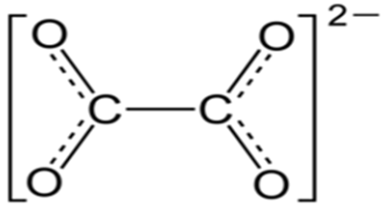

Figure 7. The structure of the oxalate anion.

1.2.8.1 Biological Function of Oxalate

Oxalate function as chelating agents and may chelate many toxic metals such as mercury and lead. But one major concern or difference between oxalate and other chelating agents is that oxalates could trap heavy metals in the tissues of living organism thereby making elimination of them very difficult.

1.2.8.2 Anti-Nutritional Effects of Oxalate

In the body, oxalic acid combines with divalent metallic cations such as calcium (Ca^{2+}) and iron (II) (Fe^{2+}) to form crystals of the corresponding oxalates which are then excreted in urine as minute crystals. Oxalate crystals can be razor sharp and may cause damage to various tissues. The sharp crystals cause damage due to their physical structure, but any contact with the crystals also increases inflammation. Iron oxalate crystals cause significant oxidative damage and diminish iron stores needed for red blood cell formation whereas many kidney stones result from calcium crystals.

These oxalates can form larger kidney stones that can obstruct the kidney tubules. An estimated 80% of kidney stones are formed from calcium oxalate [61]. Those with kidney disorders, gout, rheumatoid arthritis, or certain forms of chronic vulvar pain (vulvodynia) are typically advised to avoid foods high in oxalic acid. Methods to reduce the oxalate content in food are of current interest [62].

In studies with rats, calcium supplements given along with foods high in oxalic acid can cause calcium oxalate to precipitate out in the gut and reduce the levels of oxalate absorbed by the body, by 97% in some cases [63, 64]. Although unusual, consumption of oxalates (for example, the grazing of animals on oxalate-containing plants such as greasewood or human consumption of sorrel) may result in kidney disease or even death due to oxalate poisoning. The presence of *Oxalobacter formigenes* in the gut flora can prevent this. Cadmium catalyzes the transformation of vitamin C into oxalic acid and can result from smoking heavily, ingesting produce tainted with Cd or from industrial exposure to Cd.

1.2.9 Phenols

Phenols, sometimes called phenolics (Fig. 8), are a class of chemical compounds consisting of a hydroxyl group (-OH) bonded directly to an aromatic hydrocarbon group. The simplest of the class is phenol, which is also called carbolic acid, C_6H_5OH. Phenolic compounds are classified as simple phenols or polyphenols based on the number of phenol units in the molecule [65, 66, 67]. It is a crystalline aromatic organic compound which is a constituent of coal tar. Dilute solutions of phenol are useful antiseptics, but strong solutions of phenols are caustic and scarring to tissues. Phenols are widely used in the manufacture of resins, plastics, insecticides, explosives, dyes and detergents and as raw materials for the productions of medicinal drugs such as aspirin [68].

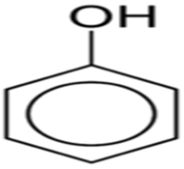

Figure 8. Phenols. Other names: Carbolic acid, benzenol, phenylic acid

1.2.9.1 Biological Function of Phenols

In plants, the phenolic units are esterified or methylated and are submitted to conjugation, which means that the natural phenols are mostly found in the glycoside form instead of the aglycone form. This property of undergoing conjugation with other molecules enables it to scavenge free radicals and thus inhibit the oxidative mechanisms that can lead to degenerative diseases such as cancer. In some cases of natural phenols, they are present in vegetative foliage to discourage herbivory, such as in the case of Western poison oak [68]. Notable sources of natural phenols in human nutrition include berries, tea, beer, olive oil, chocolate or cocoa, coffee, pomegranates, popcorn, yerba maté, fruits and fruit based drinks (including cider, wine and vinegar) and vegetables. Herbs and spices, nuts (walnuts, peanut) and algae are also potentially significant for supplying

certain natural phenols. Phenols are reported antitumour agents and exhibit antiviral and antimicrobial activities [69], hypotensive effects [70] and antioxidant properties [71].

1.2.9.2 Anti-Nutritional Effects of Phenols

Chronic ingestion of phenol can lead to nausea, vomiting, headaches, abdominal pain, sore throat, mouth ulcers and dark urine may occur, as well as respiratory and cardiovascular effects. In animals and humans, after ingestion, natural phenols become part of the xenobiotic metabolism. In subsequent phase II reactions, these activated metabolites are conjugated with charged species such as glutathione, sulfate, glycine or glucuronic acid. These reactions are catalysed by a large group of broad-specificity transferases. UGT1A6 is a human gene encoding a phenol UDP glucuronosyltransferase active on simple phenols [72]. The enzyme encoded by the gene UGT1A8 has glucuronidase activity with many substrates including coumarins, anthraquinones and flavones [73].

II. Conclusion

Plants harbor wide range of phytochemicals which help stimulate the immune system as well modulates the function of various other metabolic reactions in the body, they also act by interfering with absorption of nutrient in the body when consumed in excess and that is why phytochemicals are referred to as two edge sword. Therefore it is recommended that food sources from plants should be varied so as to eliminate the chances of over-accumulation of a particular type of phytochemical.

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