AN OVERERVIEW OF MAJOR CLASSES OF PHYTOCHEMICALS: THEIR TYPES AND ROLE IN DISEASE PREVENTION

Article · August 2018

CITATIONS
102

READS
72,567

3 authors:

Dipak Koche
Shri Shivaji College of Arts, Commerce and Science
51 PUBLICATIONS **402** CITATIONS
SEE PROFILE

R. Shirsat
Shri Dr R. G. Rathod Arts and Science college Murtizapur Dist-Akola
23 PUBLICATIONS **319** CITATIONS
SEE PROFILE

Mahesh V Kawale
Dhote Bandhu Science College, Gondia, Maharshtra, India
15 PUBLICATIONS **136** CITATIONS
SEE PROFILE

Hislopia Journal 9 (1/2) 2016
ISSN: 0976-2124 **1-11**

AN OVERERVIEW OF MAJOR CLASSES OF PHYTOCHEMICALS: THEIR TYPES AND ROLE IN DISEASE PREVENTION

DEEPAK KOCHE[1], RUPALI SHIRSAT[2] & MAHESH KAWALE[3]

[1]Department of Botany, Shri Shivaji College of Arts, Commerce and Science, Akola- 444003, (MS), India
[2]Department of Botany, Shri Dr. R. G. Rathod Arts and Science College, Murtizapur- 444107, (MS), India
[3]Department of Botany, Dhote Bandhu Science College, Kudwa Road, Gondia- 441614, (MS), India

Abstract **The green belt of Mother Nature is the richest source of bioactive phytochemicals and natural nutraceuticals. Enormous work done during the past fifty years has shown that these phytochemicals play an important role in the routine healthcare systems worldwide. The major classes of phytochemicals like alkaloids, phenolics, terpenoids and tannins have potential to prevent diseases and act as anti-microbial, anti-inflammatory, anti-oxidant, anti-cancerous, detoxifying agent, immunity-potentiating agent and neuropharmacological agent. Each class of these functional agents consists of a wide range of chemicals with differing potency. Some of these phytochemicals are found to be multifunctional. There is, however, much scope for further systematic research in screening Indian medicinal plants for their phytochemicals and assessing their potentiality as crude drug or drug components.**

Keywords **phytochemicals, nutraceuticals, biological activities**

Introduction

Phytochemicals are biologically active, naturally occurring chemical compounds found in plants, which provide health benefits for humans as medicinal ingredients and nutrients (HASLER & BLUMBERG, 1999). They protect plants from disease and damage, and also contribute to the plant's colour, aroma and flavour. In general, the plant chemicals that protect plants from environmental hazards such as pollution, stress, drought, UV exposure and pathogenic attack are called as phytochemicals (GIBSON *et al.*, 1998; MATHAI, 2000). Recently, it has been clearly shown that they also have roles in the protection of human health, when their dietary intake is significant (SAMROT *et al.*, 2009; KOCHE *et al.*, 2010). Till date over 4,500 phytochemicals have been reported and are classified on the basis of their protective functions, and physical and chemical charac-teristics, amongst these about 350 phytochemicals

have been studied in detail (KOCHE *et al.*, 2010). Wide-ranging dietary phytoche-micals are found in fruits, vegetables, legumes, whole grains, nuts, seeds, fungi, herbs and spices (MATHAI, 2000). Broccoli, cabbage, carrots, onions, garlic, whole wheat bread, tomatoes, grapes, cherries, strawberries, rasp-berries, beans and soy foods are also the common sources of phytochemicals (MOORACHIAN, 2000). Phyto-chemicals accumulate in different parts of the plants, such as in the root, stem, leaf, flower, fruit and seed (COSTA *et al.*, 1999). Many phytochemicals, particularly the pigment molecules like antho-cyanines and flavonoids, are often concentrated in the outer layers of the various plant parts like leaves and fruits of vegetables. However, the levels of these phytochemcials vary from plant to plant depending upon the variety, climatic growing conditions (RAO, 2003). These compounds have biological properties such as antioxidant activity, anti-microbial effect, modulation of detoxification enzymes, stim-ulation of the immune system, decrease of platelet aggregation and modulation of hormone metabolism and anticancer property (HAMBURGER & HOSTETTMANN, 1991). At the same time, HORBORNE (1999) reported the anti-nutritional properties of some plant chemicals.

The present review is a brief summary of the extremely diverse phytochemicals present in plants and their varied bioactivities.

Classification of Phytochemicals

The exact classification of phytochemicals has not been given so far, because of their diverse forms and structures. Classically, the phytochemicals have been classified as primary or secondary metabolites, depending on their role in plant metabolism. Primary metabolites include the common sugars, amino acids, proteins, purines and pyrimidines of nucleic acids, chlorophylls etc. Secondary metabolites are the remaining plant chemicals such as alkaloids, terpenes, flavonoids, lignans, plant steroids, curcumines, saponins, phenolics and glucosides (HAHN, 1998; RAMAWAT*et. al.*, 2009). Literature survey indicates that phenolics are the most common and structurally most diverse plant chemicals. The percent occurrence of phytochemicals in the plants and their role in human health care is given in table-1.

Phenolic Compounds

Phenolic compounds represent the largest category of phytochemicals and are most widely distributed in the plant kingdom (WALTON *et al.,* 2003). Phenolics are hydroxyl group (–OH) containing class of chemical compounds where the (–OH) group is bonded directly to an aromatic hydrocarbon group. Phenol (C_6H_5OH) is considered the simplest class of this group of natural

compounds. Being a secondary metabolite, they have an important role as defense 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. The three most important groups of dietary phenolics are flavonoids, phenolicacids and polyphenols.

Table 1.Occurrence and role of major classes of phytochemicals.

Class of phytochemical	Occurrence as natural product (%)	Role in health care
Phenolics	45	Anti-oxidants, anti-cancerous, cytotoxicants, anti-microbials and vasodilating
Terpenoids and Steroids	27	Anti-microbials, detoxifying agents, strengthners, anti-rheumatics, anti-malarial, hepaticidal
Alkaloids	18	Neuropharmaceuticals, anti-cancerous, sedatives, anti-microbials, insecticidal
Other chemicals	10	Anti-inflammatory, Immunostimulating

Flavonoids are the largest group of plant phenols and also the most studied one (DAI & MUMPER, 2010). They are polyphenolic compounds that are ubiquitous in nature and occur as aglycones, glucosides and methylated derivatives. More than 4,000 flavonoids have been recognized, many of which occur in vegetables, fruits and beverages like tea, coffee and fruit drinks (PRIDHAM, 1960). The flavonoids appear to have played a major role in successful medical treatments in ancient times, and their use has persisted up to now. 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 the position 3 or 7 and the carbohydrate unit can be L-rhamnose, D-glucose, gluco-rhamnose, galactose or arabinose (PRETORIUS, 2003). Flavonoids have gained recent attention because of their broad biological and pharmacological activities. The flavonoids have been reported to exert multiple biological properties including anti-microbial, cytotoxic,

anti-inflammatory and anti-tumor activities; but the best-described property of almost every group of flavonoids is the capacity to act as powerful antioxidants (SHIRSAT *et. al.*, 2012; TEITEN *et. al.*, 2013) which can protect the human body from the dangerous free radicals and reactive oxygen species (ROS).

Phenolic acids form a diverse group that includes the widely distributed hydroxy-benzoic and hydroxycinnamic acids. Phenolic polymers, commonly known as tannins, are compounds of high molecular weight that are divided into two classes viz. hydrolyzable tannins and condensed tannins. The term 'phenolic acids', in general, designates phenols that possess one carboxylic acid functional group. Naturally occurring phenolic acids contain two distinctive carbon frameworks viz. the hydroxycinnamic and hydroxybenzoic structures. 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 (BALSUNDARAM *et al.*, 2006). 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 than normal cells so that they are particularly sensitive to oxidative stress (MANDAL *et al.*, 2010).

Tannins

Chemically, it is difficult to define tannins since the term encompasses some very diverse oligomers and polymers (HARBORNE, 1999). 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 (SCHOFIELD*et al.*, 2001). 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.

Gallotannins- Tannins in which galloyl units or their meta-depsidic derivatives are bound to diverse polyol-, catechin-, or triterpenoid units.

Ellagitannins- Tannins in which at least two galloyl units are C–C coupled to each other and do not contain a glycosidically linked catechin unit.

Complex tannins- Tannins in which a catechin unit is bound glycosidically to a gallotannin or an ellagitannin unit.

Condensed tannins- 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 like sorghum, corn etc. (GINER-CHAVEZ, 1996). Several health benefits have been recognized for the intake of tannins and some epidemiological associa-tions with the decreased frequency of chronic diseases have been established (SERRANO *et al.*, 2009). Recently the tannins have attracted scientific interest, especially due to the increased incidence of deadly diseases such as AIDS and cancers. The search for new lead compounds for the development of novel pharma-ceuticals has become increasingly important, especially as the biological action of tannin-containing plant extracts has been well documented (MUELLER-HARVEY, 1999).

Alkaloids

Alkaloids are natural products that contain heterocyclic nitrogen atoms and are always basic in character. The name of alkaloids derives from the 'alkaline' nature and it was used to describe any nitrogen-containing base (MULLER-HARVEY, 1999). Almost all the alkaloids have a bitter taste. The alkaloid quinine, for example, is one of the bitter tasting substances known and is significantly bitter ($1x10^{-5}$) at a molar concentration (MISHRA, 1989). Alkaloids are so numerous and involve such a variety of molecular structure that their rational classification is difficult. However, the best approach is to group them into families, depending on the type of heterocyclic ring system present in the molecule (KRISHNAN *et al.*, 1983). The various classes of alkaloids according to the heterocyclic ring system they contain are listed below.

Pyrrolidine alkaloids- These contain pyrrolidine (tetrahy-dropyrrole) ring system. For example, hygrine found in leaves of *Erythroxylum* spp. &*Leonotis* spp.

Pyridine alkaloids- These have piperidine (hexahydropyridine) ring system. For example, coniine, piperine and isope-lletierine.

Pyrrolidine-pyridine alkaloids- These contain the heterocyclic ring system with pyrrolidi-nepyridine. For example myosmine, nicotine alkaloid found in tobacco (*Nicotianatabaccum*).

Pyridine-piperidine alkaloids- This family of alkaloids contains a pyridine ring system joined to a piperidine ring system. For example, anabasine alkaloid from *Anabasis aphyllan*.

Quinoline alkaloids- These have the basic heterocyclic ring system quinoline. For example, quinine

occurs in the bark of cinchona tree.

Isoquinoline alkaloids- They contain heterocyclic rig system isoquinoline. For example, opium alkaloids like narcotine, papaverine, morphine, codeine, and heroine.

Alkaloids are significant for the survival of plant because they ensure their protection against micro-organisms (antibacterial and antifungal activities), insects and herbivores (feeding deterrents) and also against other plants by means of allelopathy (MOLINEUX *et al.*, 1996). The use of 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 anti-hypertensive effects (many indole alkaloids), anti-arrhythmic effect (quini-dine, spareien), anti-malarial activity (quinine), and anti-cancer actions (dimericindoles, vincristine, vinblastine). These are just a few examples illustrating the great economic importance of this group of plant constituents. Some alkaloids have stimulant property as caffeine and nicotine, morphine are used as the analgesic and quinine as the antimalarial drug (WINK *et al.*, 1998).

Terpenoids

This class comprises 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 naturally occurring secondary metabolites (ELBEIN *et al.*, 1999). Many of these are commercially interesting because of their use as flavours and fragrances in foods and cosmetics (HORBORNE & TOMAS-BARBERAN 1991). Terpenes are widespread in nature, mainly in plants as constituents of essential oils. Their building block is the hydrocarbon isoprene, $CH_2=C(CH_3)-CH=CH_2$.

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 are also classified as hemiterpenoids.

Monoterpenoids-Monoterpen-oids have two isoprene units. Monoterpenes may be of two types i.e. linear (acyclic) or rings containing e.g. Geranyl pyrophosphate, Eucalyptol, Limon-ene, Citral, Camphor and Pinene.

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

Diterpenes- These are composed for four isoprene units. They are derived from geranyl-geranyl pyrophosphate. For example, cembrene, kahweol, taxadiene and cafestol. Retinol, retinal, and phytol are the biologically important compounds while using diterpenes as the base.

Triterpenes- These consist of six isoprene units e.g. Lanosterol and squalene found in wheat germ and olives.

Tetraterpenoids- They contain eight isoprene units which may be acyclic like lycopene, monocyclic like gamma-carotene or bicyclic like alpha- and beta-carotenes.

Among plant secondary metabolites terpenoids are a structurally most diverse group; they functions as phytoalexins in plant's direct defense or as signals in indirect defense responses, which involve herbivores and their natural enemies (MCCASKILL & CROTEAU, 1998). Many plants produce volatile terpenes in order to attract specific insects for pollination. Some plants produces less volatile but strongly bitter-tasting or toxic terpenes also protect some plants from being eaten by animals (DEGENHARDT *et al.*, 2003). In addition, terpenoids can have medicinal properties such as anti-carcinogenic (e.g. perilla alcohol), anti-malarial (e.g. artemisinin), anti-ulcer, hepaticidal, anti-microbial or diuretic (e.g. glycyrrhizin) activity and the sesquiterpenoid anti-malarial drug artimisinin and the diter-penoidanticancer drug taxol (LANGENHEIM, 1994; DUDAREVA *et al.*, 2004).

Saponin

Most members of this group form stable foam in aqueous solutions such as soap, hence the name 'saponin'. Chemically, saponins, as a group, include compounds that are glycosylated steroids, triterpenoids and steroid alkaloids. Two main types of steroid aglycones are known, spirostan and furostan derivatives. The main triterpeneaglycone is a derivative of oleanane (BOHLMANN *et al.*, 1998). 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 monodesmo-sidesaponins, and those that have a minimum of two sugars, one attached to the C-3 and one at C-22, are called bidesmoside-saponins(LASZTITY *et al.*, 1998).

Many saponins are known to be anti-microbial, to inhibit mould, and to protect plants from insect attack. Saponins may be considered a part of plants' defense systems, and as such have been included in a large group of protective molecules found in plants named phytoanticipins or phytoprotectants (LACAILLE-

DUBOIS & WAGNER, 2000). 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-permeabilizing, immunostimulant, hypocholesterolaemic and anti-carcinogenic 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 agents (MORREISSY & OSBOURN, 1999; TAKECHI*et al.*, 1999; TRAORE*et al.*, 2000).

Conclusion

Nature is a unique source of phytochemical with high diversity and many of them possessing interesting biological activities with significant medicinal properties. In the context of the worldwide scenario of different diseases, an intensive search for new lead compounds for the development of novel pharmacological therapeutics is extremely important. From the above discussion, 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 new phytochemicals might be identified as lead compounds in drug development on various diseases.

References

BALASUNDRAM, N., SUNDRAM, K. & SAMAN, S. (2006) Phenolic Compounds in Plants and Agriindustrial by-Products: Antioxidant Activity, Occurrence, and Potential Uses. *Food Chem.* 99: 191- 203.

BOHLMANN. J. MEYER-GAUEN, G. & CROTEAU, R. (1998) Plant terpenoid synthases: Molecular biology and phylogenetic analysis. *ProcNatlAcadSci* USA. 95: 4126–4133.

COSTA, M. A., ZIA, Z. Q., DAVIN, L. B. & LEWIS, N. G. (1999) Toward Engineering the Metabolic Pathways of Cancer-Preventing Lignans in Cereal Grains and Other Crops. In: *Recent Advances in Phytochemistry, vol. 33, Phytochemicals in Human Health Protection, Nutrition, and Plant Defense*, (Ed. Romeo, J. T.) New York.

DAI, J. & MUMPER, R. (2010) Plant phenolics: extraction, analysis and their antioxidant and anticancer properties. *Molecules*. 15: 7313-7352.

DEGENHARDT, J., GERSHENZON, J., BALDWIN, I. T. & KESSLER, A.(2003) Attracting friends to feast on foes: Engineering terpene emission to make crop plants more attractive to herbivore enemies. *Current Opinion Biotech*. 14: 169–176.

DUDAREVA, N., PICHERSKY, E. & GERSHENZON, J. (2004) Biochemistry of plant volatiles.*PlantPhysiology.* 135: 1893–1902.

ELBEIN, A. D. & MOLYNEUX, R. J. (1999) Comprehensive Natural Products Chemistry, Vol. 3, Barton D and Nakanishi K, ed. Amsterdam; 129.

GIBSON, E., WARDEL, J. & WATTS, C. J. (1998) Fruit and Vegetable Consumption, Nutritional Knowledge and Beliefs in Mothers and Children.*Appetite.* 31: 205-228.

GINER-CHAVEZ, B. I. (1996) Condensed tannins in tropical forages.Doctoral Thesis.Cornell University.Ithaca, NY, USA.

HAHN, N. I. (1998) Is Phytoestrogens Nature's Cure for What Ails Us? A Look at the Research.*Journal of the American Dietetic Association.*98: 974-976.

HAMBURGER, M. & HOSTETTMANN, K. (1991) Bioactivity in Plants: The Link between Phytochemistry and Medicine. *Phytochemistry.* 30: 3864-3874.

HARBORNE, J. B. & TOMAS-BARBERAN, F. A. (1991) Ecological Chemistry and Biochemistryof Plant Terpenoids, Clarendon, Oxford.

HARBORNE, J. B. (1999) An overview of antinutritional factors in higher plants. *In: Secondary plants products. Antinutritional and beneficial actions in animal feeding (Eds. Caygill, J.C. & Mueller-Harvey, I) Nottingham Univ Press, UK.*

HASLER, C. M. & BLUMBERG, J. B. (1999) Phytochemicals: Biochemistry and Physiology. *Journal ofNutrition.* 129: 756S-757S.

KRISHNAN, R., CHANDRAVADANA, M. V., RAMACHANDER, P. R. & BHARATHKUMAR, H. (1983) Inter-relationships between growth and alkaloid production in *Catharanthusroseus* G. Don. *HerbaHungarica.* 22: 47-54.

KOCHE, D., SHIRSAT, R., SYED I. & BHADANGE, D. G. (2010) Phytochemical screening of eight ethnomedicinal plants from Akola District (MS). *International Journal of Pharma and Biosci.* 1(4): 256- 259.

LACAILLE-DUBOIS, M. A. & WAGNER, H. (2000) Bioactivesaponins from plants: An update. In: *Studies in Natural Products Chemistry*; Atta-Ur-Rahman, ed. Elsevier Science. Amsterdam, 21: 633-687.

LASZTITY, R., HIDVEGI, M. & BATA, A. (1998) Saponins in food.*Food Review International.* 14: 371-390.

LANGENHEIM, J. H. (1994) Higher plant terpenoids: A phytocentric overview of their ecological roles. *Journal of Chemical Ecol.* 20: 1223- 1280.

MANDAL, S. M., CHAKRABORTY, D. & DEY, S. (2010) Phenolic acids act as signaling molecules in plant–microbe symbioses. *Plant Signal Behav.* 5: 359-368.

MATHAI, K. (2000) Nutrition in the Adult Years.*Krause's Food, Nutrition, and Diet Therapy.* 271: 274-275.

MCCASKILL, D. & CROTEAU, R. (1998) Some caveats for bioengineering terpenoid metabolism in plants. *Trends Biotech.* 16: 349–355.

MISHRA, S. N. (1989) Analytical methods for analysis of total alkaloids in root of Withania spp. *Proc.All India workshop on M & AP*, Faizabad, 492- 95.

MOLYNEUX, R. J., NASH, R. J. & ASANO, N. (1996) Alkaloids: Chemical and Biological Perspectives, Vol. 11,Pelletier SW, ed. Pergamon, Oxford; 303.

MOORACHIAN, M. E. (2000) Phytochemicals: Why and How? *Tastings*.4-5.

MORRISSEY, J. P. & OSBOURN, A. E. (1999) Fungal resistance to plant antibiotics as a mechanism of pathogenesis. *Microbiological and Molecular Biological Reviews.* 63: 708–724.

MUELLER-HARVEY, I. (1999) Tannins: their nature and biological significance. In Secondary plants products. In: *Antinutritional and beneficial actions in animal feeding* (Eds. Caygill, J.C. and Mueller-Harvey, I.)Nottingham Univ Press (UK).

PRETORIUS, J. C. (2003) Flavonoids: A Review of Its Commercial Application Potential as Anti- Infective Agents. *Current Medicinal Chemistry-Anti Infective Agents.* 2: 335-353.

PRIDHAM, J. B. (1960) Phenolics in Plants in Health and Disease, Pergamon Press, New York.

RAMAWAT, K. G., DASS, S. & MATHUR, M. (2009) The chemical diversity of bioactive molecules and Therapeutic potential of medicinal plants. In: *Herbal drugs: Ethnomedicine to modern medicine*; Springer- Verlag Berlin Heidelberg.

RAO, N. (2003)Bioactive phytochemicals in Indian foods and their potential in health promotion and disease prevention. *Asia Pacific Journal of Clinical Nutrition.* 12 (1): 9-22.

SAMROT, A., MATHEW, A. & SHYLEE, L. (2009) Evaluation of bioactivity of various Indian medicinal plants- An in vitro study.*The Internet Journal of Internal Medicine*.8(2).

SCHOFIELD, P., MBUGUA, D. M., PELL, A. N. (2001) Analysis of condensed tannins: a review.*Pharmaceutical Research.* 7: 1089-1099.

SERRANO, J., PUUPPONEN-PIMIA, R., DAUER, A., AURA, A. & SAURA-CALIXTO, F. (2009) Tannins: current knowledge of food sources, intake, bioavailability and biological effects.*Molecular Nutrition Food Research.* 53: S310–29.

SHIRSAT, R., SURADKAR, S. S. & KOCHE, D. K. (2012) Some phenolic compounds from *Salvia plebeia* R. Br. *Bioscience Discovery.* 3(1): 61-63.

TAKECHI, M., MATSUNAMI, S., NISHIZAWA, J., UNO, C. & TANAKA, Y. (1999) Haemolytic and antifungal activities of saponins or anti-ATPase and antiviral activities of cardiac glycosides. *PlantaMedica*. 65: 585–586.

TEITEN, M. H., GAASCHT, F., DICATO, M. & DIEDERICH, M. (2013) Anticancer bioactivity of compounds from medicinal plants used in European Medieval traditions. *Biochem.Pharmacol.*86(9): 1239-1247.

TRAORE, F., FAURE, R., OLLIVIER, E., GASQUET, M., AZAS, N., DEBRAUWER, L., KEITA, A., TIMON-DAVID, P. & BALANSARD, G. (2000) Structure and antiprotozoal activity of triterpenoidsaponins from Glinusoppositifolius. *PlantaMedica.* 66: 368–371.

WALTON, N. J., MAYER, M. J. & NARBAD, A. (2003) Molecules of Interest: Vanillin. *Phytochemistry.* 63: 505-515.

WINK, M., SCHMELLER, T. & LATZ-BRIINING, B. (1998) Modes of action of allelochemical alkaloids: Intraction with neuroreceptors, DNA and other molecular targets. *Journal of Chemical Ecology.* 24: 1888-1937.