Advances in Biology & Earth Sciences
Vol.5, No.2, 2020, pp. 69-75

THE BIOLOGICAL ACTIVITIES OF FLAVONOIDS AND PLANT CELL WALL POLYSACCHARIDES: A MINIREVIEW

Mebarki Lakhdar[1,2*]

[1]Laboratory of Valorization of Vegetal Resource and Food Security in Semi-arid Areas, South West of Algeria, Bechar, Algeria
[2]Department of Biology, Faculty of Natural Sciences, Tahri Mohamed University, Bechar, Algeria

Abstract. In the present review, attempts have been made to discuss the functions of flavonoids and plant cell wall polysaccharides in plants and biological activities have also been described. In plants, these substances help in combatting different biotic and abiotic stresses and act as growth regulators. In human health, most recent research suggested that these substances are responsible for the variety of pharmacological activities, such as, antioxidant, free radical scavenging, anti-inflammatory, anticancer, antiviral and antimicrobial activities.

Keywords: *Flavonoids, Plant cell wall polysaccharides, Health human, Pharmacological activities.*

Corresponding Author: *Mebarki Lakhdar, Department of Biology, Faculty of Natural Sciences, Tahri Mohamed University, BP417, Bechar, Algeria, Phone: +213 663890531,*
e-mail: Mebarki_lakhdar@yahoo.com

Received: *12 May 2020;* ***Accepted:*** *24 July 2020;* ***Published:*** *23 August 2020.*

1. Introduction

Plants derive their energy from photosynthesis, which transforms water and carbon dioxide into more or less complex compounds (Ephraim *et al*., 2014). Photosynthetic energy is divided between primary metabolism and secondary metabolism. Molecules of primary metabolism (organic acids, amino acids, proteins, simple sugars (polysaccharides), fatty acids or lipids) are essential for the growth and development of the plant. Maintained at stable concentrations, they ensure the structural and functional integrity of plant cells (Alamgir, 2018). Molecules of secondary metabolism (alkaloids, phenols, terpenes, steroids) are not always essential for the individual survival of the plant but are essential for the survival of the population (Ephraim *et al*., 2014). Their functions are to modulate the interactions of the plant with its environment (UV radiation, anti-pathogenic defenses, antioxidant molecules, pollinator attraction signals or auxiliary insects etc.) (Mebarki, 2016). Medicinal efficacy of many flavonoids and polysaccharides as antibacterial, hepatoprotective, anti-inflammatory, anticancer, and antiviral agents are well established. These substances are used worldwide but more commonly in the developing countries (Kumar and Pandey, 2013).

This review highlights the importance of flavonoids and plant cell wall polysaccharides in plants and their beneficial roles for human health.

2. Roles of polysaccharides in plant defense reactions

The plant cell wall constitutes a physical barrier to the penetration of the aggressors. To circumvent it, pathogens developed different strategies, including the production of hydrolytic enzymes that degrade the plant cell wall (Walton, 1994). The defenses of the plant include a set of mechanisms leading to alter and strengthen the cell wall against enzymatic degradation by pathogens. They include the production of hydroxyproline-rich glycoproteins (Benhamou, 1996), callose deposition and the synthesis of polyphenolic compounds such as lignin (Boudart *et al.*, 1995). In this context, hydroxyproline-rich glycoproteins are induced in various plant-pathogen interactions (Esquerré-Tugayé *et al.*, 1979). They play a role in the organization of the primary cell wall and serve as a starting point for the polymerization of lignin (Bolwell *et al.*, 1995). On the other hand, lignification reinforces the plant cell wall making it more resistant to attack by the hydrolytic enzymes of pathogens (Kawasaki *et al*, 2006). A correlation has been established between lignification and disease resistance; resistant plants show an increase in lignin deposition higher than that of sensitive plants (Soylu, 2006). In addition, callose, a constituent of parietal appositions (Cell Wall Appositions), has been considered an important factor in resistance to pathogen infection (Brown *et al.*, 1998). Indeed, plants that showed a reduction in callose deposition showed increased susceptibility to pathogens.

3. Other biological activities of plant polysaccharides

Plant cell walls are potential reservoirs of biologically active polysaccharides (Hensel *et al.*, 1998). These polysaccharides have been shown to have pharmacodynamic properties that allow their development in the health field (Diallo *et al.*, 2001). They perform important functions, such as growth regulation, pathogen defense and environmental stress. Several studies have shown that they act on diabetes (De Paula *et al.*, 2005), cancer (Ishurd & Kennedy, 2005) and also on viruses (Cassolato *et al.*, 2008).

Today, there are few immunostimulatory drugs available, and polysaccharides are the most effective immunostimulant compounds. They are devoid of toxicity and obtained from medicinal plants, may be good molecules to improve the immune system in the case of fragility of this system by diseases such as cancer, AIDS, malaria (Aboughe, 2010). Also, many articles attest to the antioxidant properties of xylans of various medicinal plants (Ebringerovà *et al.*, 2002; Kardosová *et al.*, 2004; Nabarlatz *et al.*, 2007).

In addition, natural polysaccharides from certain medicinal plants, algae and microorganisms have attracted considerable interest as antimicrobial agents (Mizuno *et al.*, 1995; Tzianabos 2000; Smith *et al.*, 2002). In recent decades, based on biotechnological methods, a series of new antimicrobial agents based on polysaccharides have been developed. They are now used in various applications, for example in the food industry to replace traditional preservatives, and in bacteriology as inhibitors of bacterial growth (Chang *et al.*, 2000). Similarly and more specifically, the antifungal activity of polysaccharide extracts has also been experimentally confirmed in several studies (Ballance *et al.*, 2007; Meera *et al.*, 2011; Chen Hao *et al.*, 2012; Mebarki *et al*, 2015; Mebarki, 2016).

4. Roles of flavonoids in plants

Flavonoids are almost universally found as pigments of plants. They are synthesized in the flowers, fruits, leaves and seeds of a large number of plants. Their accumulation confers major ecological and physiological benefits (Harborne & Williams, 2000). One of the major properties of flavonoids is to contribute to the colour of plants and especially that of flowers. However, it is by the color of its flowers, visable and sometimes invisible to the human eye, that the plant has an attracting effect on insects and pollinating birds, thereby ensuring a fundamental step in its reproduction. It should be noted that flavonoids, by repelling some insects by their unpleasant taste, can play a role in the protection of plants. Flavonoids show other interesting properties in the control of plant growth and development by interacting in a complex way with the various plant growth hormones (Chebil, 2006). On the other hand, plants use the adsorption capacity between 280 and 315 nm of all flavonoids as a protective filter against damage that can be caused by UV-B radiation on their RNA (Harborne & Williams, 2000). Some flavonoids also play a role as phytoalexins, that is to say metabolites that the plant synthesizes in large quantities after infection in defence to fungal or bacterial infection (Marfak, 2003). In this context, many flavonoids possess antifungal properties by inhibition of microbial cellulases, xylanases, pectinases, chelation of metal necessary for enzymes, and formation of a hard, almost crystalline structure as a physical barrier to pathogens. Flavonoids may cause changes in tissue differentiation and thus promote the formation of thyllus and callus, thus preventing aggression by invasive agents. Similarly, flavonoids also play an important role in the post-harvest fungal resistance of fruits and vegetables. In fact, high concentrations of flavonoids in fruit are very often correlated with a low incidence of pathogens. This observation is also used to preserve fruits better. For example, UV irradiation of *Citrus aurantium* causes an increase in flavonoid concentration and reduces *Penicillium digitatum* contamination (Treutter, 2005).

5. Other biological activities of flavonoids

Flavonoids are a group of very important substances that are of great interest in many areas. Currently, flavonoids are known by remarkable pharmaco-biological activities such as cholesterol-lowering effects, (Formica & Regelson, 1995) antiviral, antimicrobial anticancer a (Narayana *et al*., 2001; Seyoum *et al*., 2006) antiallergic, anti-inflammatory, anti-thrombotic, anti-tumor and hepatoprotective activities (Middleton *et al*., 2000). These activities are attributed in part to the antioxidant properties of these natural compounds (Saija *et al*., 1995).

In this context, according to Cushnie and Lamb (2005), different types of flavonoids (flavones, isoflavones, flavonols etc.) have exhibited antifungal, antiviral and antibacterial activity. Picman *et al*. (1995) suggested that, theoretically, flavonoids may exert antibacterial effects since they are potent inhibitors of DNA gyrase enzyme *in vitro*. In this sense, several studies have shown the bactericidal effect of different flavanones on *Staphylococcus aureus* (Sato *et al*., 1995) and several strains of Gram positive and Gram negative bacteria have been shown to be sensitive to a flavonoid glycoside (Harikrishna *et al*., 2004). On the other hand, the antifungal activity of flavonoids is also established (Mebarki *et al*., 2015; Mebarki, 2016). Because of the widespread ability of flavonoids to inhibit spore germination of phytopathogens, they have been proposed for use against fungal pathogens of humans (Harborne & Williams, 2000). Two new flavonoids, a flavone and a flavanone, respectively isolated from the fruits of *Terminalia bellerica* and the shrub *Eysenhardtia texana*, have been shown to be effective against the opportunistic pathogen *Candida albicans* (Valsaraj *et al*., 1997, Wachter , 1999). Two other flavones isolated from the plant *Artemisia giraldi* have been reported to be inhibitors of the species *Aspergillus flavus*, a fungus that causes invasive disease in immunosuppressive patients (Zheng, 1996). Galangin, a flavonol commonly found in propolis samples has been shown to inhibit *Aspergillus tamarii*, *A. flavus*, *Cladosporium sphaerospermum*, *Penicillium digitatum* and *Penicillium italicum* (Afolayan & Meyer, 1997). The mechanism of the antimicrobial effects of flavonoids may be due to the inhibition of nucleic acid synthesis (Hilliard, 1995), the inhibition of cytoplasmic membrane functions (Tsuchiya & Iinuma, 2000), the sequestration of substrate necessary for microbial growth or inhibition of microbial energy metabolism (Haraguchi *et al*., 1998).

Finaly, polysaccharides together with flavonoids *can* be *currently regarded* as a *very promising future alternative* to *conventional therapy*.

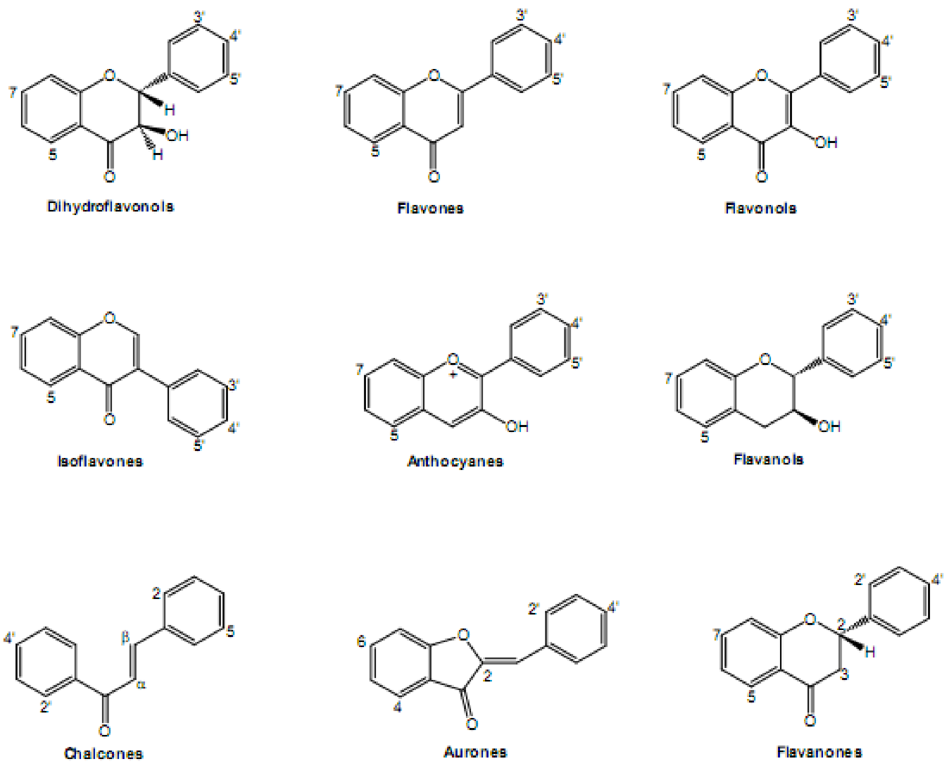

Fig. 1. Structure of the different flavonoid classes (*Hadj Salem*, 2009)

References

Aboughe, A.S. (2010). Extraction des polysaccharides hémicellulosiques de la paroi des feuilles de *Laportea aestuans* (*Fleurya aestuans*) et activité immunostimulante. *Science Sud*, 3, 1-5.

Afolayan, A.J., Meyer, J.J. (1997). The antimicrobial activity of 3,5,7-trihydroxyflavone isolated from the shoots of *Helichrysum aureonitens*. *J. Ethnopharmacol*, 57, 1777-1781.

Alamgir, A.N.M. (2018). *Therapeutic Use of Medicinal Plants and their Extracts: Phytochemistry and Bioactive Compounds*. Springer International Publishing. 826.

Balance, S., Börsheim, K.Y., Inngjerdingen, K., Paulsen, B.S., Christensen, B.E. (2007). Partial characterisation and reexamination of polysaccharides released by mild acid hydrolysis from the chlorite-treated leaves of *Sphagnum papillosum*. *Carbohydr. Polym, 67*(1), 104-115.

Benhamou, N. (1996). Elicitor-induced plant defense pathways. *Trends Plant Sci.*, 1, 233-240.

Bolwell, G.P., Butt V.S., Davies D.R., Zimmerlin A. (1995). The origin of the oxidative burst in plants. *Free Radic Res.*, 23, 517–532.

Boudart, G., Dechamp-Guillaum, G., Lafitte, C., Ricart, G., Barthe, J.P., Mazau, D., Esquerré-Tugayé, M.T. (1995). Elicitors and suppressors of hydroxyproline-rich glycoprotein accumulation are solubilized from plant cell walls by endopolygalacturonase. *Eur. J. Biochem.*, 232, 449-457.

Brown, I., Trethowan, J., Kerry, M., Mansfield, J.W., Bolwell, G.P. (1998). Localization of components of the oxidative cross-linking of glycoproteins and of callose synthesis in papillae formed during the interaction between nonpathogenic strains of *Xanthomonas campestris* and French bean mesophyll cells. *Plant J.*, 15, 333-343.

Cassolato, J.E.F, Noseda, M.D., Pujol, C.A., Pellizari, F.M., Damonte, E.B., Duarte, M.E.R. (2008). Chemical structure and antiviral activity of the sulfated heterorhamnan isolated from the green seaweed *Gayralia oxysperma*. *Carbohydr. Res.*, 343, 3085-3095.

Chang, P.S., Mukerjea, R., Fulton, D.B., Robyt J.F. (2000). Action of *Azotobacter vinelandii* poly-beta-D-mannuronic acid C-5-epimerase on synthetic D-glucuronans. *Carbohydrate. Res., 329*(4), 913-922.

Chebil, L. (2006). Acylation des flavonoïdes par les lipases de *Candida antarctica* et de *Pseudomonas cepacia* : études cinétique, structurale et conformationnelle. Thèse doctorat de l'Institut National Polytechnique de Lorraine.

Chen Hao, H., Zheng Zhou, Z., Chen Peng, P., Wu Xiang Gen, X.g., Zhao, Ge G. (2012). Inhibitory Effect of Extracellular Polysaccharide EPS-II from *Pseudoalteromonas* on *Candida* adhesion to Cornea in vitro. *Biomedl Environ Sci., 25*(2), 210–215.

Cushnie, T.T.P, Lamb, A.J. (2005). Antimicrobial activity of flavonoids. *Int. J. Antimicr. Agents, 26*(5), 343-356.

De Paula, Sousa, R.V., Figueiredo-Ribeiro, R., Buckeridge, M.S. (2005). Hypoglycemic activity of polysaccharide fractions containing β-glucans from extracts of *Rhynchelytrum repens* (Willd.) C.E. Hubb., Poaceae. B. *J. Med and Biol. Res.*, 38, 885-893.

Diallo, D., Berit, S.P., Torun HAL, Terje, E.M. (2001). Polysaccharides from the roots of *Entada africana* Guill. et Perr., Mimosaceae, with complement fixing activity. *J Ethnopharm*, 74, 159-71.

Ebringerová, A., Hromádková, Z., Heinze, T. (2005). Hemicellulose. *Adv Polym Sci.*, 186, 1-67.

Ephraim, P.L., Helena M.P., Shifra L. (2014). *Caper: the Genus Capparis*. Boca Raton, FL. CRC Press.

Esquerré-Tugayé, M.T., Lafitte, C., Mazau, D., Toppan, A., Touze A. (1979). Cell surfaces in plantmicroorganism interactions. II. Evidence for the accumulation of hydroxyprolinerich glycoproteins in the cell wall of diseased plants as a defense mechanism. *Plant Physiol.*, 64, 320–326.

Formica, J.V., Regelson, W. (1995). Review of the Biology of quercétin and related Bioflavonoids. *Fd Chem.Toxic*, 33, 1061-1080

Hadj Salem J. (2009). Extraction, identification, caractérisation des activités biologiques de flavonoïdes de Nitraria retusa et synthèse de dérivés acylés de ces molécules par voie enzymatique. Thèse de doctorat, Institut National Polytechnique de Lorraine.

Haraguchi, H., Tanimoto, K., Tamura, Y., Mizutani, K., Kinoshita, T. (1998). Mode of antibacterial action of retrochalcones from *Glycyrrhiza inflata*. *Phytochemistry*, 48, 125-129

Harborne, J.B., Williams, C.A. (2000). Advances in flavonoid research since 1992. *Phytochimistry*, 55, 481-504.

Harikrishna, D., Appa Rao, A.V.N., Prabhakar M.C. (2004). Pharmacological investigation of a flavonoid glycoside. *Indian. J. Pharmacol.*, 36, 244-250.

Hensel, A., Schmidgall, J., Kreis, W. (1998). The plant cell wall - A potential source for pharmacologically active polysaccharides. *Pharm Acta Helv.*, 73, 37-43.

Hilliard, J.J., Krause, H.M., Bernstein, J.I., Fernandez, J.A., Nguyen, V., Ohemeng, K.A., Barrett, JF. (1995). A comparison of active site binding of 4-quinolones and novel flavone gyrase inhibitors to DNA gyrase. *Adv. Exp. Med. Biol.*, 390, 59-69.

Ishurd, O,. Kennedy, J.F. (2005). The anti-cancer activity of polysaccharide prepared from Libyan dates (*Phoenix dactylifera* L.) *Carbohydr. Polym.*, 59, 531-535.

Kardosová, A., Ebringerovà, A., Alfödi, J., Nosàl'ovà, G., Matàkova, T., Hribalovà, V. (2004). Structural features and biological activity of an acidic polysaccharide complex from *Mahonia aquifolium* (Pursh) Nutt. *Carbohydr. Polym.*, 57, 165-176.

Kawasaki, T., Koita, H., Nakatsubo, T., Hasegawa, K., Wakabayashi, K., Takahashi, H., Umemura, K., Umezawa, T., Shimamoto, K. (2006). Cinnamoyl-CoA reductase, a key enzyme in lignin biosynthesis, is an effector of small GTPase Rac in defense signaling in rice. *Proc Natl. Acad. Sci. USA*, 103, 230-235.

Kumar, S., Pandey Abhay, K. (2013). Chemistry and Biological Activities of Flavonoids: An Overview. *Sci World J.*, 16 pages.

Marfak, A. (2003). Radiolyse Gamma des Flavonoïdes. Etude de Leur Réactivité avec Les Radicaux issus des Alcools: Formation de depsides. Thèse de doctorat. Université de Limoges, p: 187

Mebarki, L., Kaid Harche, M., Benlarbi, L., Kasmi, H., Matrouine, M. (2015). *Bubonium graveolens* extracts for controlling *Fusarium oxysporum* f. sp. *albedinis*. *Rom Biotechnol Lett.*, *20*(1), 10026-10035.

Mebarki, L. (2016). Search of biological activity of plant molecules for controling *Fusarium oxysporum f. sp. albedinis*. PhD thesis, USTOMB, Oran, Algeria, 191 p.

Meera, C.R., Syama, C., Rakhi, J., Wilsy, W., Anjana, J.C and Ruveena, T.N. (2011). Antimicrobial and Anti-Oxidant Activities of Polysaccharides Isolated from an Edible Mushroom, *Pleurotus florida. Adv. Bio. Tech.*, *10*(08), 12-13

Middleton, E., Kandaswami, C,. Thioharidies, T.C. (2000). The effects of plant flavonoids on mammalian cells: implications for inflammation, heart disease and cancer. *Pharmacolo Rev.*, 52, 673-751.

Mizuno, T., Sakai, T., Chihara, G. (1995). Health foods and medicinal usage of mushrooms. *Food Rev. Int.*, *11*(1), 69-81.

Nabarlatz, D., Montané, D., Kardosovà, A., Bekesová, S., Hribalovà, V., Ebringerová, A. (2007). Almond shell xylo-oligosaccharides exhibiting immunostimulatory activity. *Carbohydr. Res.*, 342, 1122-1128.

Narayana, K.R, Reddy, M.S., Chaluvadi, M.R., Krishina, D.R. (2001). Bioflavonoids classification, pharmacological, biochemical effects and therapeutic potential. *Indian J. Pharmacol.*, 33, 2-16.

Picman, A.K., Schneder, E.F., Picman J. (1995). Effect of flavonoids on mycelial growth of *Verticillium*. *Albo Atrum Biochem. Sys. and Eco.*, 23, 683-693.

Saija, A., Scalese, M., Lanza, M., Marzullo, D., Bonina, F. Castelli, F. (1995). Flavonoids as antioxidant agents importance of their interaction with biomembranes. *Free Radic. Biol. Med.*, 19, 481-486.

Sato, M., Tsuchiya, H., Takase, I., Kureshiro, H., Tanigaki, S., Iinuma M. (1995). Antibacterial activity of flavanone isolated from *Sophora exigua* against methicillin-resistant *Staphylococcus aureus* and its combination with antibiotics. *Phytother. Res.*, 9, 509-512.

Seyoum, A., Asres, K., El-Fiky, F.K. (2006). Structure-radical scavenging activity relationships of flavonoids. *J. phytochem.*, 67, 2058-2070.

Smith, J.E, Rowan, N.J, Sullivan R. (2002). Immunomodulatory activities of mushroom glucans and polysaccharide-protein complexes in animals and humans. In: *Medicinal Mushrooms:*

Their therapeutic properties and current medical usage with special emphasis on cancer treatments. University of Strathclyde and Cancer Research U.K.: Glasgow, U.K., 106-141.

Soylu, S. (2006). Accumulation of cell-wall bound phenolic compounds and phytoalexin in Arabidopsis thaliana leaves following inoculation with pathovars of *Pseudomonas syringae*. *Plant Sci.*, 170, 942–952.

Treutter, D. (2005). Etude phytochimique et évaluation biologique de *Derris ferruginea* Benth. (Fabaceae). Thèse de doctorat, Université d'Angers.

Tsuchiya, H., Iinuma M. (2000). Reduction of membrane fluidity by antibacterial sophoraflavanone G isolated from Sophora exigua. *Phytomed.*, 7, 161–165.

Tzianabos, A. (2000). Polysaccharide immunomodulators as therapeutic agents: structural aspects and biologic function. *Clin. Microbiol. Rev.*, *13*(4), 523-533.

Valsaraj, R., Pushpangadan, P., Smitt, U.W., Adsersen, A., Christensen, S.B., Sittie, A., Nyman, U., Nielsen, C., Olsen, C.E. (1997). New anti-HIV-1, antimalarial, and antifungal compounds from Terminalia bellerica. *J. Nat. Prod.*, 60, 739-742.

Wachter, G.A., Hoffmann, J.J, Furbacher, T., Blake, M.E, Timmermann, B.N. (1999). Antibacterial and antifungal flavanones from *Eysenhardtia texana*. *Phytochem.*, 52, 1469-1471.

Walton, J.D. (1994). Deconstructing the cell wall. *Plant Physiol.*, 104, 1113-1118.

Zheng, W.F, Tan, R.X, Yang, L., Liu, Z.L. (1996). Two flavones from *Artemisia giraldii* and their antimicrobial activity. *Planta. Med.*, 62, 160-162.