Chapter 16

Flavonoids: Important Biocompounds in Food

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http://dx.doi.org/10.5772/67864

Abstract

Flavonoids are secondary metabolites in plants that show some desirable characteristics. These compounds can be grouped in different classes on the basis of their basic structure. It has been reported that flavonoids are important for human health because of their antioxidant, antibacterial, antiviral, and anti-inflammatory activities and because they act as free radical scavengers as they are potential reducing agents that protect from oxidative damage, which are conferred by the content of hydroxyl groups. In recent years, flavonoids have been investigated based on their ability to reduce the incidence of many diseases, to inhibit cell damage, to repair DNA process and to reduce oxidative stress. Besides, flavonoids have been demonstrated to have cardioprotective effects, have potential to improve coronary vasodilatation and prevent LDLs from oxidizing and also showed potential neuroprotective effects. Moreover, flavonoids have been used in the food industry due to their ability to preserve foods, to provide colour and flavour and to make dietary supplements, among other important industrial applications.

Keywords: biocompound, flavonoid, antioxidant

1. Introduction

Plant metabolites can be divided into two groups: primary metabolites, which are involved in the nutrition and the essential metabolic processes (e.g. carbohydrates, lipids and proteins); and secondary ones, which have an important function in the interaction between a plant and its environment, such as pigments or defensive compounds. Secondary metabolites included a group of compounds known as phenolic; in this group, we can find the flavonoids.

Flavonoids are a large group of natural substances with variable structures present almost in all growing parts of the plants, being reported as the most abundant plant pigment along with chlorophyll and carotenoids, also providing fragrance and taste to fruits, flowers and seeds, which makes them attractants for other organisms [1, 2]. These compounds are also one of the largest groups of secondary metabolites [3]. Besides their relevance in plants, flavonoids are important for human health because of their high pharmacological activities. Recent interest in these substances has been stimulated by the potential health benefits arising from the antioxidant activities of these polyphenolic compounds.

In this chapter, we focused in the antioxidant, antibacterial, antiviral and anti-inflammatory activities of flavonoids, which according to many studies are conferred mainly by the content of hydroxyl groups attached to base structures of these compounds. Biochemical actions of these compounds depend primarily on the presence and position of their substituent groups, which can affect the metabolism of each one [4]. One of the most important characteristics of flavonoids is that they often occur in the glycosidic form, which possibly let them take place in the gastrointestinal tract [5].

However, they attract attention due to their antioxidant activity and reduce free radical formation and also scavenge free radicals [6]. Flavonoids have other important biological activities such as protect skin from UV light exposure, protect DNA from damage, strengthening of capillaries, anti-inflammatory effect and protective action against radiation, moistening, softening, soothing, antiseptic and other. Due these properties, flavonoids can be used as ingredients in the production of cosmetics and pharmaceutical products [7, 8].

Nowadays, flavonoids are major bioactive compounds known for their potential health benefits, which have been used against many chronic diseases such as cancer, antiviral, inflammation, cardiovascular and neurodegenerative disorders; it is widely assumed that active dietary constituents are antioxidant nutrients present in fruits and vegetables [9].

2. Classification

In general, all flavonoids have a general structural compound with a chromane-type skeleton composed of three phenolic rings referred to as A, B and C rings (**Figure 1**) with phenyl

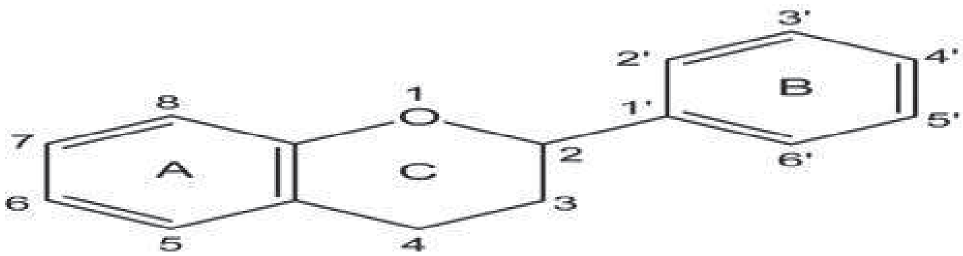


Figure 1. Flavonoid basic structure [13].

http://dx.doi.org/10.5772/67864

substituent in the C2 or C3 position in B ring. Their functions depend on their structural class, degree of hydroxylation and conjugation and degree of polymerization. They vary in the structure around the heterocyclic oxygen ring, but all have the characteristic C6-C3-C6 carbon skeleton [3, 10–12].

They can be grouped into different classes with respect to the basic structure, which allows a wide substitution patron and variations in C ring leading to their classification [11].

2.1. Flavones

In the classification, we can find that in the main structure of *flavones* a double bond between carbons 2 and 3 of the central ring is present (**Table 1**). Also, the structure of flavones has a carbonyl group in position 4 in C ring. These types of flavonoids are pale yellow in colour, and their representative forms are apigenin, chrysin, myricetin, rutin, sibelin, luteolin, diosmetin and quercetin [5, 14–17]

2.2. Flavonols

As flavones, *flavonols'* structure exhibits a double bond between carbons 2 and 3, and a carbonyl group in carbon 4, also a hydroxyl group in carbon 3 of C ring, for example, quercetin, rhamnetin and kaempferol.

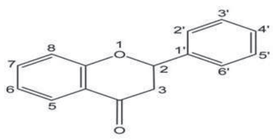
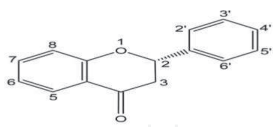
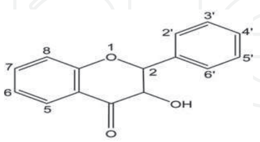
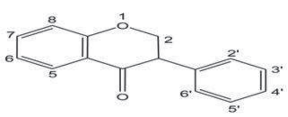
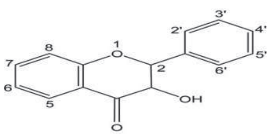
	Structure	Position	3	5	7	3′	4′	5′
Flavones		Apigenin	-	OH	OH	-	OH	-
		Luteolin	-	OH	OH	OH	OH	-
		Chrysin	-	OH	OH	-	-	-
Flavonones		Naringenin	-	OH	OH	OH	OH	-
		Hesperetin	-	OH	OH	-	OH	-
		Neohesperetin	-	OH	OH	-	-	-
Flavonols		Quercetin	-	OH	OH	OH	OH	-
		Kaempferol	-	OH	OH	-	OH	-
		Galangin	-	OH	OH	-	-	-
Isoflavones		Genistein	-	OH	OH	-	OH	-
		Daidzein	-	OH	OH	-	-	-
		Glycitein	-	OH	OH	-	-	-
Flavanols		(+) – catechin	βOH	OH	OH	OH	OH	-
		(–) + epicatechin	αOH	OH	OH	OH	OH	-
		(–) – epigallocatechin	αOH	OH	OH	OH	OH	OH

Table 1. Flavonoid subgroup structures and their different substitution patterns [13, 23].

2.3. Flavanones

The basic structural model of flavanones has 2-phenylbenzopiran-4-one-skeleton. These compounds are of great interest due to the fact that they play an important role in the metabolic pathway of the other flavonoids. Their metabolic precursors are chalcones, flavones, dihydroflavonols; isoflavones are biosynthesized from the flavanones [18]. Their chemical structures have a hydroxyl group in 3 position of C ring [19]. Physically, some flavanones are colourless (Hesperidin), pale (naringenin, eriodictyol) and others yellow (neohesperidin) [15, 16].

2.4. Flavanols

Flavanols, well known as flavan-3-ols or catechin, have a hydroxyl group in C3 of C ring, with no carbonyl group. These flavonoids are colourless (catechins, gallocatechin, epicatechin, epigallocatechin, gallate) and some of them show yellow colouration (procyanidin, theaflavines).

2.5. Anthocyanidines

This is the other subgroup, which structurally has a hydroxyl group in 3 position and also a double bond between carbons 3 and 4 of C ring. These molecules are water soluble, and are the pigments responsible for the red to purple color in plants.

2.6. Isoflavones

This is a distinctive subclass of flavonoids. They structurally have a 3-phenylchromone skeleton with same three phenolic rings referred to as A, B and C rings. But also, in some of their derivative compounds, they can form an additional heterocyclic ring (D ring) (rotenoid, coumestane, pterocarpan) [20].

3. Flavonoids in foods

Flavonoids are synthesized in all parts of the plant. They provide colour, fragrance and taste to the fruits, flowers and seeds, which make them attractants for insects, birds and mammals, which aid in pollen or seed transmission [2]. Flavonoid distribution in plants is affected by different factors, including variation and exposure degree of light. The production of high oxidized flavonoids is accelerated by light [21]. Major classes of flavonoids based on abundance in food are flavonols, flavones, isoflavones, flavanones, flavandiols, anthocyanins, proanthocyanidins and cathechins. Other classes of flavonoids include flavan-3-ols, anthocyanidins, chalcones, and other biosynthetic intermediates of the flavonoid biosynthesis are aurones, bioflavonoids and dihydrochalcones [22].

The content of flavonoids in food varies, which depends on the source, vegetable, fruits or seeds, as well as processed food. The content of some important flavonoids in foods such as cabbage, spinach, carrots, peas, mushrooms, peaches, strawberries, orange juice, white wine or brewed coffee is low or <10 mg/kg or L. In some other vegetables and fruits, such as lettuce, beans, red pepper, tomato, grapes, cherries, red wine and tea, their content is < 50 mg/kg or L. On the other hand, their content in broccoli, kale, French beans, celery and cranberries is high, over 50 mg/kg or L. Apple contains flavonoids such as quercetin (184 mg) and epicatechin (180 mg) in approximate 120 g of flesh with 80 g of skin [24]. Citrus fruit such as oranges and grapefruits contain flavonoids such as naringin and hesperidin. Naringin is mainly present in grapefruits and sour oranges, while hesperidin is present in sweat oranges, mandarins and lemons. In addition, 500 ml of orange juice contains 292 mg of hesperidin [25, 26]. Berry fruits (strawberries, blueberries and cranberries) contain high levels of anthocyanins in their skin and flesh; strawberries contain 33.63 mg per 100 g, whereas blueberries contain 13.52 mg [27]. Onions contain up to 22 mg of quercetin per 100 g [28]. **Table 2** shows various classes of flavonoids and some of their food sources.

Flavonoid subgroup	Source	Specific flavonoid	Reference
	Erica andevalensis, Garcinia kola (seeds), Achyrocline satureioides, Silydum marianum, Scutellaria baicalensis		[32]
Anthocyanins	Fruits and flowers, blueberries, bananas, strawberries, red wine, cranberries, blackcurrants	Anthocyanidin, cyanidin, delphinidin, malvidin, pelargonidin, petunidin, peonidin	[21, 27, 33, 34]
Flavanols (flavan-3-ols)	Apples, Hops, green tea, Beer, kiwi, cocoa products	Catechins, gallactocatechins, epicatechin, epigallocatechin gallate	[24, 33–36]
	Wine, fruit juice	Procyanidin	
	Black tea	Theaflavins	
Flavanones	Citrus fruits, curcumin, oranges, grapefruits, peppermint, lemon	Hesperidin, Naringenin Neohesperidin. eriodictyol	[9, 25, 33, 37]
	Tomato		
Flavones	Herbs, cereals, fruits, parsley, thyme, bee pollen, passiflora plant	Apigenin, chrysin, luteolin	[33, 34, 38, 49]
	Vegetables, flowers	Diosmetin, luteolin	
Flavonols	Onions, cherries, apples, broccoli, kale, tomatoes, berries, black tea, red wine, tartary buckwheat, edible part of plants, leeks, bee pollen, citrus fruits	Isorhamnetin, kaempferol, quercetin, myricetin, rutin, pinocembrin	[24, 28, 38–40]
	Yellow wax and ancho peppers, canned kale		
Flavanonols	Lemon, aurantium	Taxifolin	[21]
Isoflavones	Legumes (soybeans), soy products, miso tofu	Daizein, genistein, glycitein, formononetin, biochanin A	[33, 37]

Table 2. Food sources of flavonoids.

4. Antioxidant activity

The best described property of almost all groups of flavonoids is their powerful antioxidants, which act as free radical scavengers as they are potential reducing agents and protect from oxidative reactions taking place inside the body [22]. The antioxidant activity of flavonoids is due a combination of their iron chelating and free radical scavenger properties, also the inhibition of oxidases enzymes such as lipoxygenase, cyclooxygenase, myeloperoxidase, NADPH oxidase and xanthine oxidase; avoiding thereby the formation of reactive oxygen species and organic hydroperoxides [19]. Moreover, flavonoids can inhibit enzymes by indirectly involving in the oxidative process, such as phospholipase A2, at the same flavonoids can stimulate other enzymes with antioxidant activities like catalyse and superoxide dismutase.

This feature depends of their molecular structure. This free radical scavenging activity is primarily attributed to the high reactivity of hydroxyl substituents. For example, by scavenging free radicals, the hydroxyl group on the B-ring donates hydrogen and an electron to hydroxyl, peroxyl and peroxynitrite free radicals, stabilizing them, because of the high reactivity of the hydroxyl group of the flavonoids, radicals are made inactive according to Eq. (1), where R* is a free radical and O* is the oxygen free radical) [17, 29–31].

$$\text{F-OH} + \text{R}\bullet \rightarrow \text{F-O}\bullet + \text{RH} \tag{1}$$

The significance of other hydroxyl configuration is less clear, but beyond increasing total number of hydroxyl groups, A-ring substitution correlates little with antioxidant activity. Similarly, the difference in antioxidant activity between polyhydroxylated and polymethoxylated flavonoids is most likely due to differences in both hydrophobicity and molecular planarity [30].

A lot of studies have realized the antioxidant activity of flavonoids. Majewska et al. [41] evaluated different flavonoids and compared their antioxidant activity with DPPH radical. The flavonoids such as quercetin, rhamnetin, isorhamnetin, luteolin and apigenin were tested and the results showed that quercetin has the highest antioxidant potential at lower concentration (0.1–5 μg/sample). In other studies, Choi et al. [42] tested the inhibitory activity of xanthine oxidase, linoleic acid peroxidation and scavenging capacity of DPPH with some flavonoids, and obtained the following results at a concentration of 100 μg/ml: for xanthine oxidase, catechin, morin, naringenin and quercetin showed 100% of inhibition, and rutin only 43%; for linoleic acid peroxidation, quercetin showed the highest inhibition (82%), followed by catechin (71%), rutin (63%), morin (56%), naringenin (53%); and finally for DPPH catechin, morin and quercetin obtained a high activity (100%) than rutin (95%), naringenin did not show any data.

On the other hand, using an aqueous emulsion of linoleic acid/β-carotene at 50°C, and compared with synthetic antioxidant BHT, D,L-α-tocopherol and its acetate, Burda and Oleszk [43] examined the antioxidant activity of some flavonoids and observed the highest values were obtained by synthetic ones (88–95%) and slightly lower, but still high antioxidant activity was shown by a group that included fisetin (61%), kaempferol (65%), galangin (64%), quercetin (63%), robinetin (61%), morin (63%) and kaempferide (60%), all of these are flavonols with a free hydroxyl group at the C-3 position.

5. Health benefits

Flavonoids are a widely distributed group of polyphenols and comprise the most studied bioactive compounds for about 50 years due their potential health benefits; they have a complex and unknown biologic function, which are based on their antioxidant activity [9, 39, 44, 45]. Furthermore, because of their remarkable activities and potential health benefits, they are used in the food and cosmetics industries. Their functions can be divided in two (i) general or nonspecific activity (related to the presence of phenolic compounds) and (ii) specific activity (depends on the particular chemical and structural characteristics of the active compound) [46], which are presented in **Table 3**.

The decrease in consumption of fruits and vegetables has been associated with several diseases. Flavonoids attract attention due to their ability to reduce the incidence of many diseases. Its recommended intake or supplementation of flavonoids with a combination of another antioxidants, vitamins and minerals can reduce incidence of cancer, cardiovascular mortality and ischemic vascular disease [39, 49–53]. According to many studies, in flavonoid-rich foods the daily intake of these compounds can be range between 50 and 800 mg/day, mainly with the consumption of fruits and vegetables [6, 54]. However, is also known that flavonoids inhibit proliferation of viruses like herpes simplex, polio and pseudorabies [47]. On the other hand, some results from other different studies have demonstrated that in very high doses, flavonoids can act as pro-oxidant; so, it is important to consider the recommended daily intake of these compounds to promote their functions on the organism [55].

For many years, plants have been used like traditional Mexican medicine due to their medicinal potential of crude extracts (mainly rich in flavonoids) to the treatment of diarrhoea and stomach diseases [55]. This potential can be attributed for many physiological functions, such as their antioxidant, antibacterial and antigiardial activities to reduce the incidence of this kind of diseases [54].

Nonspecific activity	Specific activity
Absorption of ultraviolet radiation	Affinity to estrogenic receptors
Reactive oxygen species neutralization	Anti-inflammatory activity
Inhibition of radical reactions	Impact on cardiovascular system
Chelating trace metals	Influence on regulatory systems and tissue signal transmission
Inhibition of enzymes	Microorganism growth inhibition
Activation of antioxidant enzymes	Interaction with enzymes
Interactions with membranes	Interaction with transcription factors
Antioxidant properties	Interaction with receptors

Table 3. Biological functions of flavonoids on humans [46–48].

In recent years, flavonoids have gained interest in health as protective agents against many diseases, which involve radical damage [56]. Likewise, many epidemiological studies have been developed to show the association between consumption of vegetables and fruits and the risk of disease such as cancer, neurological and cardiovascular diseases [57]. Some authors show beneficial results of flavonoids against diseases; studies about the dietary called French paradox revealed that flavonoid-rich diet is directly correlated with decrease incidence of cardiovascular diseases and increase longevity on Mediterranean population, which is associated with consumption of red wine and low-fat diets [58].

5.1. Anticancer effect of flavonoids

Cancer is a multifactorial heterogeneous disease, which is the main cause of death in some countries along with cardiovascular diseases, and it is expected to increase about 70% cases in the next 20 years. These have been related to different factors of behavioural and dietary risks, among which are the reduced consumption of vegetables, limited physical activity and consumption of alcohol and tobacco, which may cause negative impact on health [59, 60].

According to some studies, flavonoids have some pharmacological properties that inhibit cell damage [61]. Herrera et al. [51] conducted a study and evaluated the efficiency of supplementation with correct antioxidant content to reduce cancer incidence; these trials concluded that antioxidant supplementation may inhibit cancer incidence only in healthy subjects. But according with Hollman and Katan [62], bioactive compounds may inhibit various stages in cancer process.

Some studies in animals with some types of chemical carcinogen-induced or transplanted tumours have been shown good results about the prevention development and growth of various types of cancer. Some mechanisms of biologically active substances, including their antioxidant activity, may act on stages of carcinogenesis such as initiation, promotion and progression. Flavonoids can inactive the carcinogen, inhibit cell proliferation, repair DNA processes and reduce oxidative stress (in initiation and promotion stages); in the progression stage, they may exhibit antioxidant activity, induce apoptosis and develop cytotoxic action against cancer cells [4, 63]. Because inflammation is closely related to tumour promotion, bioactive compounds like flavonoids are expected to exert chemopreventive effects against carcinogenesis, especially in promotion and progression stages, and are estimated to reduce risk of cancer [64].

5.2. Flavonoids on the cardiovascular system

In the last decade, cardiovascular diseases increased the number of death around the world; this is due to the decrease in consumption of fruits and vegetables, and it is estimated that these diseases will continue affecting the population [65]. Antioxidant properties of flavonoids are interesting due their potential role in prevention of cardiovascular diseases. Other authors suggested that these compounds decrease the risk of coronary diseases, but nevertheless, their antioxidant and chelating properties are the major mechanisms to inhibit or inactivate reactive oxygen species, which play an important role to affect cardiovascular system [9, 63].

According to some authors, the mechanistic pathways of flavonoids on cardioprotection include some actions, such as improving coronary vasodilatation, decreasing the ability of platelets in the blood to clot, preventing LDLs from oxidizing, inhibition of inflammation propagation, antiapoptotic, antinecrotic, free radical scavenging abilities and its crucial role in the impact on capillary blood vessel [9, 47, 57].

Rice-Evans et al. [5] studied the correlation with the intake of flavonoids and risk of death from coronary heart disease on a group of Dutch population; these epidemiological study showed that intake natural flavonoids can reduce 2.4 times cardiovascular diseases compared people with lower intake of these bioactive compounds. They established that antioxidant and antithrombotic properties contribute to this protection and may provide a better lifestyle.

5.3. Flavonoids on the nervous system

In recent years, experimental and clinical studies have been reported that flavonoids not only have benefits against cancer and cardiovascular diseases. The interest in consumption of flavonoids has been addressed due their potential neuroprective effects to prevent different diseases related to nervous system such as Alzheimer, Parkinson and slow down cognitive decline, which can generate dementia [45]. Diets rich in these substances (at low concentration) were shown beneficial effects to maintain human cognitive functions to promote improvements in memory, protect vulnerable neurons, stimulate neuronal regeneration and prevent oxidative neuronal damages [66].

Reactive oxygen, nitrogen species, inflammatory responses and their mediators are involved in the development in the pathogenesis of various neurodegenerative diseases [61]. Recent works have revealed that flavonoid-rich food intake (for 8 weeks) provides positive effects on neurocognitive functions due to its antioxidant activity and is effective in reversing age-related deficits in brain. Previous studies in rats showed that the application of natural extracts rich in polyphenolic compounds represent an important advance to use of these extracts to the generation of nutraceuticals products to improve health in humans [44]. According some authors, the neurobiological actions of these compounds may occur in two major ways: the first is regulation of the neuronal signal cellular cascades, which is caused by neurotoxic substances and may damage neurogenesis, neuronal function and brain connectivity. Second, flavonoids seem to improve blood-flow toward brain and sensory systems and exert beneficial effects on the peripheral and central nervous [4, 63].

6. Applications in food

In recent years, many polyphenols have been used as natural antioxidants in oils and fats to prevent lipid oxidation, protect food and beverages from light exposure, to prolong shelf-life of food, supplement for animal feeds to improve their health, to protect animal products, like antimicrobial agent in foodstuffs and health functional ingredient in foods and dietary supplements; these applications can be attributed mainly to antioxidant and antimicrobial activities [47, 67, 68]. The use of synthetic additives in the food industry has been declining in recent years; this is mainly because man seeks to reduce risk in suffering from diseases which have been associated with synthetic products consumption. Flavonoids are phytochemicals that cannot be synthesized by humans; however, these compounds may be used as food additives to improve health-beneficial effects and increase their amount in humans [69, 70].

Flavonoids are present in significant amounts in many fruits and vegetables; natural antioxidants and flavonoids have been reported as two of the most important micronutrients, which can be used in industry to reduce the use of synthetic compounds on foods and improve health in humans due their potential to decrease several diseases. These bioactive compounds can be used to prolong shelf-life and preserve many foods due to their antimicrobial and antioxidant properties [44]. Moreover, in recent years interest in acquiring ever more natural products has grown; this has been caused by restriction over the use of synthetic antioxidants in food (such as BHA and BHT) and increase the use of natural compounds such as antioxidants or food components, which have relatively low toxicity compared to synthetic products [57, 65].

Flavonoids are suitable compounds that may be used as food preservative due to their beneficial effects that have been demonstrated before: prevention of fat and oils oxidation, supplement for animal feeds, protection of vitamins and enzymes, inhibition of microbial growth in foodstuffs and health functional ingredient in foods and dietary supplements [68]. The most studied applications of flavonoids in foods are in red meats and poultry to inhibit lipid oxidation, use of natural extracts in foods as functional ingredients and retard spoilage microorganism growth in meats. Some studies have indicated that these compounds have protective effect on meat quality and other products [67].

Recently, flavonoids have gained attention due their antioxidant properties, which can act against oxygen free radical and lipid peroxidation [71]. Many studies have mentioned that *in vitro* antioxidant activity of these compounds depends on the arrangement of functional groups on its structures; however, the mechanism of their antioxidant activity is substantially influenced by their configuration and total number of hydroxyl groups presents in the flavonoid molecule and the glycosylation of flavonoid molecule, but could be increased by polymerization of flavonoid monomers [58, 72, 73].

The protective effect of flavonoids in biological systems is attributed to their antioxidant activity due to their capability to donate a hydrogen atom [58]. However, it is important to consider the antioxidant effect *in vivo*, which can be different comparing with *in vitro* assays: (i) low concentration on systemic circulation compared with endogenous and exogenous antioxidant compounds, (ii) high level of biotransformation that flavonoids suffer during their absorption and distribution in the body, which can decrease their antioxidant activity and (iii) large doses of flavonoids may decrease bioavailability of trace elements, such vitamins, folic acid or other antioxidants [4, 74].

7. Other applications

Plant bioactive compounds (primarily flavonoids) have been used in dermatology and cosmetic preparations for a long time due to several associated properties such as antioxidant,

http://dx.doi.org/10.5772/67864

antimicrobial, anti-inflammatory and therapeutic properties [8, 75]. Flavonoids are gaining popularity as cosmetic ingredients because they can protect skin from UV light and cure the skin from oxidative stress, so they can improve skin appearance [76]. The activity of flavonoids on the skin is associated with their antiradical properties due to the presence of phenolic groups, but these activities on the skin are poorly investigated. Many studies have been demonstrated that the scavenging of flavonoids depends mainly to a high degree on their structures and physicochemical properties [47].

In order to protect the skin against UV radiation, the use of herbal and biodegradable products has been increased; cosmetic products are being recognized for their benefits in the prevention of various pathologies and in the improvement of several dermatologic conditions, which represent a viable alternative for industrial application of natural extracts [70, 76]. Recent dermatological studies have been demonstrated that herbal extracts were added to cosmetic preparations due to antioxidant properties of flavonoids in addition to impart UV protection and inhibit metal chelating properties to protect skin [75].

The protective action of flavonoids on the skin is manifested through their anti-inflammatory activity. This activity is given by the action of bioactive compounds on the enzymes and other factors that promote inflammation stages. The other mechanism of action is the inhibition of enzymes linked to cellular activation that promotes skin deterioration and the secretion of regulatory substances for their propagation. The affinity for protein structures and with estrogen receptors is another property of flavonoids, as well as anti-irradiating activities; because of these features, they are used in the cosmetic industry to reduce congestion problems, with the aim of reducing inflammatory symptoms that damage humans [47].

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