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ScienceDirect
Food Chemistry 104 (2007) 466–479
Food Chemistry
www.elsevier.com/locate/foodchem

Citrus flavonoids: Molecular structure, biological activity and nutritional properties: A review

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Received 6 September 2006; received in revised form 11 October 2006; accepted 22 November 2006

Abstract

Epidemiological studies have shown an inverse relationship between dietary flavonoid intakes and cardiovascular diseases. *Citrus* fruits are the main winter fruits consumed in the Mediterranean diet, so they are the main source of dietary flavonoids. The possible beneficial effects are due, not only to the high amounts of vitamins and minerals, but also to the antioxidant properties of their flavonoids. Dietary flavonoids may help to supplement the body antioxidant defences against free radicals. These compounds' possible beneficial effects are due to their antioxidant activity, which is related to the development of atherosclerosis and cancer, and to anti-inflammatory and antimicrobial activity. The present review summarizes the existing bibliography on biological and pharmacological studies of *Citrus* flavonoids, both *in vitro* and *in vivo*.

Keywords: Citrus fruits; Flavonoids; Antioxidant; Atherosclerosis; Cancer

1. Introduction

The possible beneficial effects of foods are due to micronutrients (for example vitamins and minerals) and to functional food ingredients and antioxidant nutraceuticals, "phytochemical substances". Phytochemicals can be defined as substances found in edible fruits and vegetables that, daily ingested, may exhibit a potential for modulating human metabolism in a manner favourable for the prevention of chronic and degenerative diseases. Nowadays, many studies are carried out on the thousands of phytochemicals that may have important physiological effects. An increased consumption of fruit and vegetables, typical Mediterranean diet foods, may protect against degenerative pathologies, such as cancer and atherosclerosis (Hertog, Hollman, & Katan, 1992; Keys, 1995). Epidemiological studies have shown an inverse relationship between dietary flavonoid intake and cardiovascular diseases (Hertog, Hollman, Katan, & Kromhout, 1993). Among the phytochemicals, flavonoids are widely contained in *Citrus* fruits (Yao et al., 2004). *Citrus* fruits are the principal source of such important nutrients. They contain vitamin C, folate, dietary fibre and other bioactive components, such as carotenoids and flavonoids, which are suggested to be responsible for the prevention of cancer and degenerative diseases (Ejaz, Ejaz, Matsuda, & Chae, 2006).We will consider the biological activity and the healthy effects of *Citrus* flavonoids as antioxidant compounds.

2. The *Citrus* flavonoids

According to their molecular structures, flavonoids are divided into six classes: flavones, flavanones, flavonols, isoflavones, anthocyanidins and flavanols (or catechins) (Fig. 1) (Peterson, Dwyer, & Dsc, 1998). Flavonoids

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doi:10.1016/j.foodchem.2006.11.054

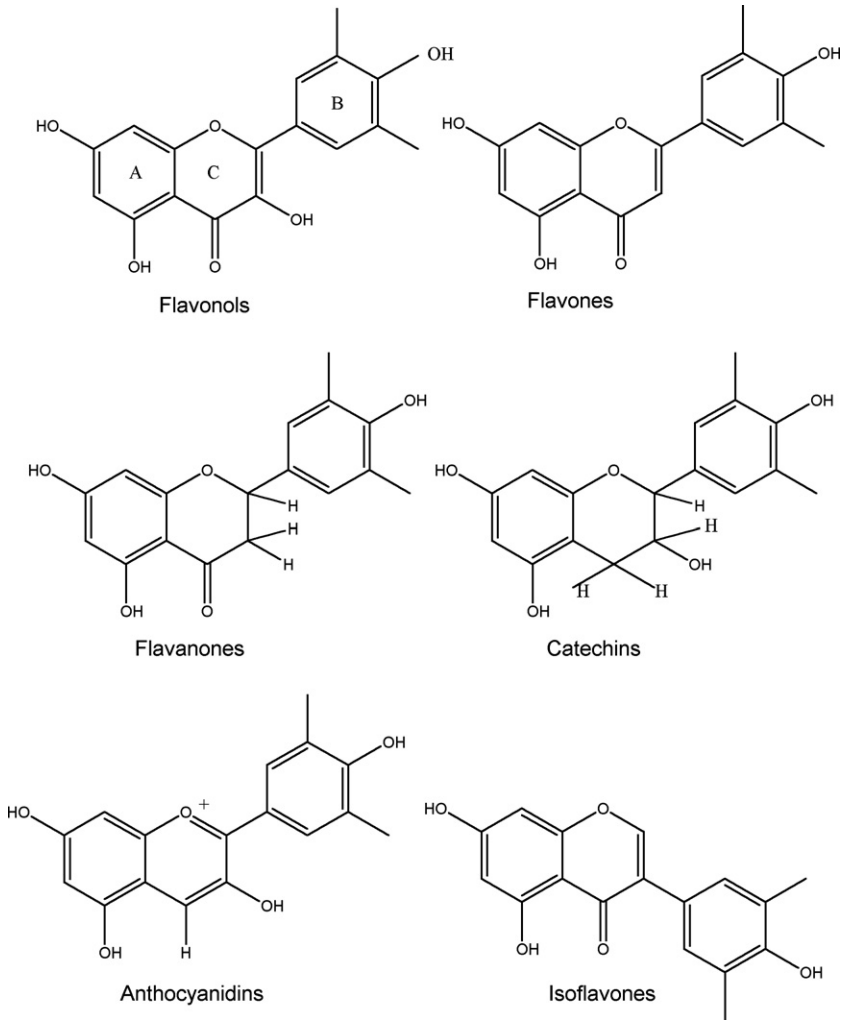

Fig. 1. Molecular structures of flavonoids. The basic structure consists of the fused A and C ring, with the phenyl ring B attached to through its 1′ position to the 2-position of the C ring (numbered from the pyran oxygen).

identified in *Citrus* fruits cover over 60 types, according to the five classes mentioned (Horowitz & Gentili, 1977): flavones, flavanones, flavonols, flavans and anthocyanins (the last only in blood oranges). Table 1 shows the main chemical structures of some flavonoids isolated from *Citrus* fruits, their structures (flavanone, flavone, or flavonol) and their chemical groups.

Citrus flavanones are present in the glycoside or aglycone forms. Among the aglycone forms, naringenin and hesperetin are the most important flavanones (Table 1). Among the glycoside forms, two types are classified: neohesperidosides and rutinosides (Gionfriddo, Postorino, & Bovalo, 1996; Macheix, Fleuriet, & Billot, 1990). Neohesperidosides, flavanones, naringin, neohesperidin and neoeriocitrin consist of a flavanone with neohesperidose (rhamnosyl-α-1,2 glucose) and they have a bitter taste (Table 1), while rutinosides (flavanones, hesperidin, narirutin and didymin) have a flavanone and a disaccharide residue e.g. rutinose (ramnosyl-α-1,6 glucose) and they are without taste (Table 1). Flavanones are usually present in diglycoside form, conferring the typical taste to *Citrus* fruits (Macheix et al., 1990).

Phenolic compounds and flavonoid profiles are detected by HPLC-MS. These compounds can be divided into two groups according to the lag-times: the first eluted are flavanone glycosides while the second group are polymethoxylated flavones (subsequently eluted they are less polar) (Fig. 2) (Mouly, Gaydou, & Auffray, 1998).

Among flavonoids, the anthocyanins are structurally derived from pyran or flavan and, in particular, oxygen attributes a basic property to this molecule. They can be present as aglycones (anthocyanidins metabolites of flavones) (Fig. 1).

Catechins, leucoanthocyanin and proanthocyanins are in the flavan group, as also are tannins. They can be found in monomer, dimer and polymer forms, respectively monoflavans, biflavans or triflavans (Cook & Samman, 1996).

3. Distribution of *Citrus* flavonoids

Flavonoids are a group of pigments contained in plants and they are responsible for flower and fruit colouration. Flavonoids are present in dietary fruits and vegetables (Macheix et al., 1990). The *Citrus* peel and seeds are very