ABSTRACT: Recent studies have documented a number of health benefits associated with the consumption of citrus. These fruits are predominantly composed of water and have a very low energy density. However, they are some of the most important nutrient-dense foods available. In effect, citrus fruits contain a range of key nutrients such as vitamin C, folate, dietary fiber, minerals (potassium) and phytochemicals, which confer them the health-promoting properties. In recent years, there has been increasing interest in the anti-oxidant capacity of foods. Vitamin C is a major contributor to the anti-oxidant capacity of citrus. However, the major contribution of citrus anti-oxidant activity comes from the combination of phytochemicals and from their synergistic action with vitamin C. The major phytochemicals in citrus fruits are the terpenes and phenolic compounds, which possess anti-inflammatory and anti-carcinogenic activity. Carotenoids and limonoids are terpenes that are released in the processing of juices. Citrus is the main source of specific nutrients such as flavanones (hesperetin and naringenin, usually present as glycosides) and the carotenoid cryptoxanthin, which are not present in other fruits in significant quantities. Flavonoids also have a role in cardiovascular protection, inhibiting the formation of atheroma in many steps of its pathogenesis.

KEY WORDS: Citrus, Flavonoids, Limonoids, Vitamin C

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FUNCTIONAL FOODS

Functional foods have been defined as “foods that, by virtue of the presence of physiologically active components, provide a health benefit beyond basic nutrition” (International Life Sciences Institute, 1999). All foods are functional to some extent. However, some foods are now being examined intensively for added physiologic benefits; such foods may reduce chronic disease risk or otherwise optimize health. A term often erroneously used interchangeably with functional foods is “nutraceuticals”, coined to refer to nearly any bioactive component that delivers a health benefit. However, a food is a complex mixture of biologically active substances, and its overall effect on health will not only relate to the balance of these components within the food itself but also how they interact with or complement components from other foods and how overall dietary intake interacts a) with other non-dietary risk factors for health and b) with the genetic and biological profile of the individual.

CITRUS FRUITS

Epidemiological data support the association between a high intake of vegetables and fruits and a low risk of chronic disease (Radhika et al., 2008; Jew et al., 2009). A wide range of bioactive substances for which potential health effects have been postulated have already been identified in foods and it is likely that many more exist. These include vitamins, trace minerals, dietary fiber, and a range of phytochemicals.

One class of fruits that have recently received increasing attention in relation to health outcome is the citrus fruits. Recent studies have documented a number of health benefits associated with their consumption. In some cases, the data suggest that the incidence, severity and mortality from several diseases, such as cardiovascular diseases, certain types of cancer, and obesity, might be ameliorated by the consumption of additional citrus fruit and/or juices. Overall, the literature indicates that citrus fruits provide a protective effect and play a specific role in counteracting some of these conditions; the nutritional benefits of citrus are related, in part, to their anti-oxidative capacity, as well as their nutrient content of vitamin C, folate and potassium and fiber content. More recently, the role of non-nutrient components, such as phytochemicals, has emerged.
Citrus fruits have long been considered a valuable part of a healthy, tasty, and nutritious diet and are the main fruits grown and consumed in the world, in part because their flavors are among the most preferred. Citrus fruits constitute several species of the genus Citrus of the subfamily Aurantioidae of the plant family Rutaceae. The Aurantioidae has a total of thirty-three mostly subtropical and tropical genera, a few of which have economic importance. Most genera originated in Southeast Asia, including the Malaysian and Indonesian Archipelagos, the Indo-Malayan Peninsula, India, and China. A few genera originated in Australia and in Africa. The genus Citrus is divided into two subgenera, Citrus and Papeda. The former contains “edible” citrus fruits (including some less than palatable varieties).

The taxonomy of Citrus, as a genus, is unclear (Khan, 2007). Currently, the generally accepted concept is that there are three primordial or fundamental Citrus species: Citrus medica (citrons), Citrus maxima (pummelos), and Citrus reticulata (mandarins). Edible citrus is generally divided into sweet oranges, sour oranges, mandarins, grapefruit, pummelos, lemons, limes, and citrons. In general, Citrus cultivars have undergone numerous genetic modifications due to frequent spontaneous mutations, free or controlled hybridizations and natural selection, giving rise to various types and subtypes (Table 1). The major types consumed in the world are oranges, mandarins, lemons, grapefruits and limes. Some of these (low-acid sweet oranges, sour oranges, and citrons) are not of much importance commercially, while others (sweet lemons and sweet limes) are important in some regions of the world but not in others.

**Citrus fruit anatomy**

The citrus fruits are characterized by their distinctive fruit, the hesperidium, which is a berry with the internal fleshy parts divided into segments (typically 10 to 16) and surrounded by a separable skin. The name is derived from classical mythology, referring to the “golden apples” grown in the garden of the Hesperides (the daughters of Hesperus, the evening star) in Paradise.

Parts of the fruit:

- **Exocarp.** The exocarp forms the tough outer skin of the fruit, which bears oil glands and pigments. Also known as the *flavedo*, it is mostly composed of cellulosic material but also contains other components, such as essential oils, paraffin waxes, steroids and triterpenoids, fatty acids, pigments (carotenoids, chlorophylls and flavonoids), bitter principles (limonene) and enzymes.

- **Mesocarp.** In a hesperidium such as a citrus fruit, the mesocarp is also referred to as the *albedo*. It is a spongy white tissue of soft fiber and also contains bitter compounds such as limonoids. It is part of the peel, which is commonly removed by hand.

- **Endocarp.** The endocarp is the inside layer, which directly surrounds the seeds. It is membranous and the main part consumed. It is separated into sections, most commonly called segments. In the membranous layers (partitions) surrounding the seed-bearing sections and in the seeds are limonoids. The juice vesicles or sacs in the segments fill with liquid that contains water, sugars, vitamins, minerals and phytochemicals such as flavonoids. The juice sacs constitute the fleshy, edible pulp of the fruit and are the source of the sweet juice.

<table>
<thead>
<tr>
<th>Original species</th>
<th>Citrus maxima, the pummelo, from the Malay archipelago</th>
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<tbody>
<tr>
<td>Citrus medicana, the citron, from India</td>
<td></td>
</tr>
<tr>
<td>Citrus reticulata, the mandarin, from China</td>
<td></td>
</tr>
<tr>
<td>and perhaps, Citrus aurantiifolia, the key lime, from India</td>
<td></td>
</tr>
</tbody>
</table>

**Major hybrids**

| Citrus sinensis, sweet orange |
| Citrus aurantiifolia, bitter orange |
| Citrus paradisi, grapefruit |
| Citrus limonia, Rangpur lime |
| Citrus latifolia, Persian lime |

**TABLE 1. Taxonomy of Citrus fruit**

**NUTRIENT COMPONENTS OF CITRUS FRUIT**

Like most fruits, citrus fruits are predominantly composed of water and are very low in energy density. However, they are some of the most important nutrient dense foods, which provide an array of essential nutrients for human health. Citrus fruit contains a range of key nutrients such as vitamin C, vitamin A, folate, dietary fiber, and minerals, which confer them with significant health benefits. As such, they are discussed in the section on functional components below.

The calorie values of 100 g of oranges, mandarins, grapefruit and lemons are 35, 34, 22, and 15 Kcal, respectively. Protein content ranges from 0.69 (grapefruit) to 0.94 (mandarin) gram per 100 g of fruit. Citrus fruits also contain other nitrogen compounds such as amines, the more important being synephrine, found mainly in sour oranges and grapefruits, and lemons contain octopamin and tiron. Citrus fruits are very low in fat, ranging from 0.1 to 0.31 per 100 g, which is located in the seeds and flavado. The carbohydrate content (including sugars) ranges from 8.4 to 10.5 g per 100 g of the edible portion. The total sugars range from 3.2 to 8.5 g per 100 g. Grapefruits have relatively less total carbohydrates and sugars than oranges, mandarins or lemons. The carbohydrates in citrus are such that these foods have a low glycemic index. Dietary fiber ranges from 2.5 to 0.6 g per 100 g of the edible portion from lemon to grapefruit.

**FUNCTIONAL COMPONENTS OF CITRUS FRUITS**

The membranous segments of citrus fruits have the highest content of bioactive compounds. As such, it is recommended that the fresh fruit or the juice with high pulp content be consumed to assure its intake.
Minerals

Citrus fruit contains a range of minerals including Ca, Fe, Mg, P, K, Zn, Cu, Mn, and Se. These fruits are particularly high in potassium (potassium content ranges from 135 to 181 mg/100 g of the edible portion) but extremely low in sodium (from 0 to 2 mg/100 g). This potassium to sodium ratio promotes the regulation of blood pressure (Fang et al., 2006). Although citrus fruits are relatively low in iron content (from 0.06 to 0.15 mg/100 g of the edible portion), their high vitamin C content helps release iron from other foods, so that citrus plays a valuable role in iron homeostasis. Therefore, the consumption of citrus foods with non-heme iron-containing foods is recommended to optimize iron absorption.

Vitamins

The major vitamin present in citrus fruit is vitamin C. Other vitamins present in citrus fruits are folate and vitamin A in the form of its precursor β-carotene and cryptoxanthin. Citrus fruits are generally not a major source of B vitamins, other than folate.

Vitamin C

Citrus fruit are rich in vitamin C (ascorbic acid), ranging from 26.7 to 53.2 mg per 100 g of the edible fruit. This water-soluble vitamin is an essential micronutrient. The daily recommended value for vitamin C for adults is 60 mg/day. Thus, one serving of a medium orange (154 g), which provides 82 mg vitamin C, is more than the recommended daily intake of this important nutrient. The variability in the vitamin C content of citrus fruits and their products is influenced by variety, maturity, climate and storage conditions. Immature fruits contain the highest concentrations of vitamin C; these levels decrease during ripening (Cano et al., 2008). Vitamin C has multiple biochemical roles, including its role as a cofactor for several enzymes involved in the biosynthesis of collagen, carnitine and neurotransmitters. It is involved in tissue repair and is necessary for prevention of the deficiency disease scurvy. It has also been suggested that vitamin C may promote collagen formation and reduce osteoporosis to maintain bone mass (Sahni et al., 2009).

In recent years, there has been increasing interest in the anti-oxidant capacity of vitamin C. Vitamin C is a major contributor to the anti-oxidant capacity of fruits (Martí et al., 2009). It scavenges reactive oxygen and nitrogen species; 200-500 mg appears to be the level needed to optimize its anti-oxidant effect. Vitamin C can also act as a co-anti-oxidant by regenerating α-tocopherol (Vitamin E) from the α-tocopheroxy radical produced by scavenging lipid-soluble radicals. It has also been shown that vitamin C protects against in vivo oxidation of lipids and nucleic acids (Ren et al., 2010).

It has been reported that vitamin C is associated with the prevention of degenerative processes such as cardiovascular disease due to its effect on low density lipoprotein (LDL) and triglyceride levels in the blood (Houston, 2010; Abdollahzad et al., 2009). In addition, vitamin C was found to be directly associated with high density lipoprotein (HDL) by inhibiting HDL lipid oxidation (Calla and Lynch, 2006). Vitamin C may also play a protective role against stroke (Myint, et al., 2008), asthma (Patel et al., 2006), and enhancement of the immune system by stimulating the production of white blood cells (Wintergerst et al., 2007). In relation to cancer, vitamin C may provide protection through several mechanisms in addition to its inhibition of DNA oxidation. One proposed mechanism involves chemoprotection against mutagenic compounds, such as nitrosamines (Erkekoglu and Baydar, 2010). However, the majority of the total anti-oxidant activity in citrus fruits is due to their combination of phytochemicals, not from vitamin C alone (Sun, 2002).

Vitamin A

Although citrus fruit do not contain vitamin A as such, they contain vitamin A retinol equivalents, ranging from 2 µg of edible portion in the lime to 25 µg in the orange, mainly in the form of the precursor β-carotene (10-130 µg of β-carotene) and, to a lesser extent, cryptoxanthin, which contribute to vitamin A levels. Vitamin A is essential for normal growth, vision and cell structure. It confers protection on the linings of the respiratory, digestive and urinary systems. Vitamin A deficiency is the leading cause of preventable blindness in children and increases the risk of disease and death from severe infections (Ayazi et al., 2010). In pregnant women, vitamin A deficiency causes night blindness and may increase the risk of maternal mortality (Bryce et al., 2008).

Folate

Folate plays an important metabolic role as a coenzyme in amino acid metabolism, nucleic acid synthesis and in other biochemical reactions requiring the transfer of a methyl group to a biological acceptor molecule. The principal forms of folate in citrus are the reduced 5-methyl tetrahydrofolate and polyglutamate derivatives. Citrus fruits are a good source of folate, with contents ranging from 11 mg/100 g in lemons to 30 mg/100 g in oranges. The consumption of a medium orange (154 g) a day provides about 12% of the Recommended Daily Allowances (RDA, 400 µg/day). Because methylation of DNA is an important mechanism for controlling the expression of many genes, including those involved in cell proliferation, folate has been implicated as a protective factor against a number of conditions, including cancer (Hubner and Houlston, 2009). Its effect on DNA methylation may also play a role in the prevention of neural tube defects such as spina bifida (van der Linden et al., 2006). Folate may be involved in the prevention of cardiovascular disease, where it acts as a co-factor in the...
enzymatic methyl group transfer from homocysteine to the essential dietary amino acid methionine (Anderson et al. 2010).

Phytochemicals

Phytochemicals are defined as substances found in edible fruits and vegetables that, when ingested on a daily basis, exhibit a potential for modulating human metabolism in a manner favorable to the prevention of chronic and degenerative diseases. Deficiencies of phytochemicals in the diet do not lead to the deficiency diseases seen with low intakes of more traditional nutrients, such as vitamins; rather it is possible that these substances contribute to optimal health (Hasler et al., 2004). The major phytochemicals in citrus fruits are terpenes and phenolic compounds.

Terpenes

Citrus fruits contain monoterpene, triterpene (limonoids) and tetraterpene (carotenoids). Limonene is a monocyclic monoterpen found in citrus oils, garlic and the oils of other plants. It can have properties to block and suppress the carcinogenic events (Sun, 2007). The most abundant terpenes in citrus are the limonoids (Figure 1), which are present in neutral (monocarboxylated/aglycon) as well as acidic (carboxylated/glucoside) forms; the former are insoluble and bitter, and the latter are soluble and tasteless (Roy and Saraf, 2006). Citrus seeds constitute the only natural repository of citrus limonoid aglycone, with limonin being the most abundant. In animal experiments, terpenes have shown to have powerful anticancer properties, which are attributed to their structure, which incorporates a distinctive furan or hydrated furan functionality in addition to epoxide and lactone functional groups (Manners, 2007).

Limonoids can prevent the incorporation of the growth signaling ras proteins into membranes, which become damaged and uncontrollable early in the process of carcinogenesis. In addition, they may stimulate enzymes that are thought to detoxify other chemicals, and they have been shown to suppress the growth of tumor cells in vivo and in vitro (Poulase et al., 2005). These compounds appear relatively stable and may act synergistically with other potential anticancer agents in model systems. Other effects described are mainly anti-viral (Battinelli et al., 2003) and hypcholesterolemic (Manners, 2007).

The carotenoids are tetraterpenes that give plants their color. More than 600 carotenoids have been identified, but only a few are of interest in human nutrition: α-carotene, β-carotene, lycopen, lutein, zeaxanthin and cryptoxanthin. These six carotenoids are all found in citrus fruits.

- β-carotene is one of the better known carotenones because of its high vitamin A activity and its distribution in nature. The protective effects of β-carotene may be associated with anti-oxidant protection, having the highest anti-oxidant potential in the citrus peels (Guimarães et al., 2010). β-carotene is also related to the enhancement of the immune response (Imamura et al., 2006).

- Lycopen is an open-chain unsaturated carotenoid that imparts red color to the cara-cara navel orange and pink grapefruit (Alquezar et al., 2008). As with β-carotene, lycopen is a proven anti-oxidant.

- Cryptoxanthin is abundant, especially in mandarins. Cryptoxanthin has been attributed with preventive effects on cancer (Nishino et al., 2009), counteracts induced bone loss in vivo (Uchiyama et al., 2006), and has a positive effect on serum lipid levels (Sugiura et al., 2004).

Phenolic compounds

Phenolic compounds or polyphenolics encompass a wide variety of naturally occurring compounds that are structurally related to the extent that they all contain one or more benzene rings, each with one or more hydroxyl group substitutions. Under this general rubric are the simple phenols, the hydroxycinnamic acid derivatives, the flavonoids, the coumarins and the furanocoumarins.

Polyphenols are thought to play a number of roles in plants. For example, they help protect the plant from attack by pathogens and predators due to their anti-microbial properties and astringent taste, and polyphenols are responsible for many of the skin colors of fruit and vegetables. They have been shown to have a range of health related effects, due principally to their anti-oxidant and anti-inflammatory properties.

<table>
<thead>
<tr>
<th>Flavanones</th>
<th>Glycosilated</th>
<th>Hexamethoxyflavone</th>
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<tbody>
<tr>
<td>Aglycone: naringenin and hesperitin</td>
<td></td>
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<tr>
<td>Glycoside forms: two types are classified</td>
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<td></td>
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<tr>
<td>Neohesperidosides: naringin, neohesperidin, neoeiriocitrin</td>
<td></td>
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<tr>
<td>Rutinosides: hesperidin, narirutin, didymin</td>
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<td></td>
</tr>
<tr>
<td>Flavones</td>
<td>Glycosilated</td>
<td>Heptamethoxyflavone</td>
</tr>
<tr>
<td></td>
<td>Rohifolin</td>
<td>Nobiletin</td>
</tr>
<tr>
<td></td>
<td>Isorohifolin</td>
<td>Scutellarein</td>
</tr>
<tr>
<td></td>
<td>Diosmin</td>
<td>Heptamethoxyflavone</td>
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<tr>
<td></td>
<td>Neodiosmin</td>
<td>Tangeretin</td>
</tr>
<tr>
<td></td>
<td>Polymethoxylated</td>
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</tbody>
</table>
FIGURE 2. Flavonoid structure

The polyphenol category of flavonoids is a group of low molecular weight polyphenolic compounds that are widely distributed in plants and are particularly abundant in citrus plants. Flavonoids are pigments responsible for fruit coloration. The citrus peel and seeds are very rich in phenolic compounds, such as phenolic acids and flavonoids. The peels are richer in flavonoids than are the seeds. Citrus juice also contains flavonoids in an appreciable amount (Sendra et al., 2006).

Flavonoids identified in citrus fruits cover over 60 types, of which there are four classes: flavanones, flavones, flavanols and anthocyanins, with the last present only in blood oranges (Tripoli et al., 2007). Flavanones and flavones are the major flavonoid classes present in citrus fruit. The most abundant flavonoids in all citrus fruits are the 7-O-glycosylflavanones. Flavanones are present in greater quantities than flavones, but the highly methoxylated flavones have higher biological activity, even at lower concentrations. The main polymethoxylated flavones present in citrus are tangeretin, nobiletin and sinesitin. The concentration of these components depends upon the age of the plant; most citrus species accumulate substantial quantities of flavonoids during organ development. The major flavonoids in citrus are shown in Table 2.

The health effects of flavonoids include the following.

1. Anti-oxidant activity: Flavonoids have to be able to act as anti-oxidants by scavenging free radicals (Benavente-García and Castillo, 2008). According to kinetic studies, the anti-oxidant capacity of a flavonoid is linked to its particular chemical structure. Three structural groups are important: the ortho-dyhydroxy (catechol) structure in the B-ring, the 2, 3 double-bond, in conjugation with a 4-oxo function, and the presence of both 3-(a)-and 5-(B)-hydroxyl groups (Di Majo et al., 2005). They have the ability to act as reducing agents, making them capable of donating hydrogens to free radicals to neutralize their damaging effects (Ghasemi et al., 2009). Flavonoids can also act as chelators of transition metals (Renugadevi and Prabu, 2010).

2. Anti-inflammatory activity: Flavonoid action on the immune and inflammatory responses is associated with their inhibition of key enzymes (i.e., lipoxygenase, phospholipase, and cyclooxygenase) that control the biosynthesis of proinflammatory mediators, mainly the arachidonic acid derivatives, prostaglandins E2 and F2, thromboxane A2, and other biological mediators responsible for the activation of endothelial cells. Citrus flavonoids are able to inhibit the kinases and phosphodiesterases essential for cellular signal transduction and activation (Lee et al., 2009) and inhibit cells involved in inflammation and the immune response (Manthey, 2009).

3. Anti-atherosclerotic activity: Flavonoids are involved in cardiovascular protection, mainly derived from its anti-oxidant and anti-inflammatory activity. They inhibit the formation of atheroma at several steps during its pathogenesis. An initial event in atherosclerosis is the oxidation of LDL promoted by reactive oxygen species. The uptake of oxidatively modified lipoproteins by macrophages transforms these cells into foam cells, which are a major component of atherosclerotic plaques. Flavonoids may reduce the generation of free radicals in macrophages (Lo et al. 2010) or may protect LDL from oxidation by regenerating active α-tocopherol (Kadoma et al. 2006). Another effect of free radicals (mainly superoxide anion) is the rapid inactivation of endothelial-derived nitric oxide, which is an important factor for the maintenance of normal vascular homeostasis. In this sense, naringenin and hesperetin (the aglycone form of hesperidin), two major flavanones in citrus plants, positively enhance endothelial nitric oxide production (Liu et al., 2008). Flavonoids also influence other critical functions in the vascular system, including inhibition of platelet aggregation (Jin et al., 2007), thereby reducing the risk of clot formation. In addition, a reduction in plasma cholesterol by citrus flavonoids is associated with effects on specific liver functions related to lipid processing. Polymethoxylated flavones reduced plasma cholesterol levels at lower doses than those required for flavanones (Morin et al., 2008).

On the other hand, it has been shown that specific flavonoids (mainly bergamottin and naringenin in the grapefruit (de Castro et al., 2008)) can inhibit drug-metabolizing enzymes such as CYP3A4 involved in xenobiotic metabolism. In this way these components may interact with pharmacological agents such as β-blockers or cholesterol-lowering statins increasing the risk of overdose.
4. **Anti-carcinogenic activity**: Flavonoids are potentially involved in several aspects of carcinogenesis, not only due to their effect as antioxidants.

- **Anti-mutagenic effects**: Flavonoids may protect DNA from oxidative damage and neutralize free radicals that promote mutations (Jagetia et al., 2003).

- **Anti-proliferative effects**: Various mechanisms have been proposed to explain the anti-proliferative activities of flavonoids. These mechanisms are likely mediated by the inhibition of several kinases involved in cell-cycle arrest and apoptosis. The nature of this inhibition depends upon the particular structure of each flavonoid. The higher activity of flavones compared to flavonones can be attributed to the presence of a C2-C3 double bond. As such, the lipophilic polymethoxylated flavones (nobiletin and tangeretin) inhibit squamous-cell carcinoma cells in a dose-dependent manner (Tripoli et al., 2007). The planar structure and the last two small substituents (hydroxyl or methoxyl) in the A or B rings of the flavonol skeleton are essential (Rodriguez et al., 2002). Hesperidin, a known flavonoid constituent of citrus, reduces the in vitro proliferation of many cancer cells types such as human colon cancer cells (Park et al., 2008).

- **Anti-angiogenic effects**: Tumor angiogenesis is of critical importance in the development and metastatic spread of tumors. Citrus flavonoids are able to inhibit several key events in the angiogenic process, such as the proliferation and migration of endothelial cells and vascular smooth muscle cells and the expression of two major pro-angiogenic factors, vascular endothelial growth factor (VEGF) and matrix metalloproteinase-2 (MMP-2) (Schindler and Mentlein, 2006).

5. **Anti-infectious activity**: Flavonoids have shown both antimicrobial and anti-viral activities. The latter appears to be associated with non-glycosidic compounds, and hydroxylation at the 3-position is apparently a prerequisite for anti-viral activity. This anti-viral activity has been shown in vitro against influenza virus (Saha et al., 2009) and hepatitis C virus, which is actively secreted by infected cells through a Golgi-dependent mechanism while bound to very low density lipoprotein (Nahmias et al., 2008).

**Coumarins**

Citrus peels contain a number of coumarins that possess mevalonate-derived side chains with various levels of oxidation. Their effects are related to the suppression of superoxide generation and lipid peroxidation as well as the induction of phase II drug metabolizing enzymes. Human studies with citrus fruit and experimental studies with coumarins suggest that these substances may protect against several human cancers, but data are still limited (Sekiguchi et al., 2010). Auraptene is the most common coumarin in citrus and is found in sour oranges (C. aurantium) and grapefruit (C. paradisi). Citrus fruit products such as grapefruit juice and marmalade retain some auraptene activity.

Other phytochemicals

Citrus also contain other phytochemicals, including phytoestrogens such as enterolactone (27 µg/100 g orange) and enterodiol (12 µg/100 g orange); lignins such as secoisolariciresinol (76.8 µg/100 g orange and 61.3 µg/100 g lemon); and phenylpropanoids such as caffeic acid (84 ppm orange) and p-coumaric acid (25-60 ppm grapefruit and 21-182 ppm orange). However, levels of these phytochemicals are relatively low in citrus compared with other fruits and drinks such as tea.

**Fiber**

Citrus fruits are a good source of dietary fiber because they are rich in pectin, cellulose, hemicellulose and lignin, ranging from 0.6 g/100 g (grapefruit) to 2.5 g/100 g (lemons). Most citrus fiber is contained in the peel, albedo, membrane and juice sac. As with other foods, fiber shortens transit times through the gut and produces high stool weights. Possibility more important, however, is the capacity of the bacterial flora in the large bowel to ferment the fiber. The short-chain fatty acids (SCFA) generated by fermentation include butyric acid, which is a preferred energy substrate for colonocytes. Fermentation may also release sequestered minerals (like calcium) and reduce bowel pH; both of these effects act in concert to precipitate harmful bile acids. These properties can be useful in treating gastrointestinal problems such as constipation and diverticular disorders. Because of its “bulk” effect, fiber enhances glycemic control, reduces serum cholesterol levels and promotes satiety (Theuwissen and Mensink, 2008). In this sense, whole fruit provides greater satiety than juice. Instead of drinking one serving of orange juice (8 oz, 110 calories), a person who eats a medium orange (154 g) consumes only 62 calories and obtains more fiber and bulk.

**POSSIBLE HEALTH BENEFITS OF CITRUS FRUIT CONSUMPTION**

The health benefits of citrus consumption by the persons have been related, in part, to their anti-oxidative capacity as well as their content of nutrients such as fiber, folate and potassium. Ascorbic acid (vitamin C) accounts for a large proportion of nutritional anti-oxidant activity. However, other non-nutrient dietary components, such as carotenoids and polyphenols (e.g., flavonoids), may also contribute anti-oxidant activity. While ascorbate and carotenoid concentrations in humans can be elevated by the intake of a variety of fruits and vegetables (Sun et al., 2002), only few of them, such as citrus, provide specific flavanones (hesperetin and naringenin, usually as glycosides) and the carotenoid cryptoxanthin and constitute a major source of these nutrients.

**Citrus fruit consumption and cardiovascular risk**

The effect of diet on cardiovascular risk includes potential effects on vascular endothelial dysfunction, which appears to be closely related to inflammatory processes. Vascular
endothelial dysfunction is also an early precursor to the development of atherosclerosis. Several components in citrus fruits can act synergistically to counteract these risks. In epidemiological studies, a significant association between vitamin C intake in foods and protection against cardiovascular mortality has been shown, along with an inverse relationship with markers of inflammation (Wannamethee et al., 2006). Citrus fruits are characterized by high concentrations of other bioactive components that are specialized anti-oxidants: the polyphenols. It is possible that the synergistic effect of the combination of citrus compounds counteracts the progression of cardiovascular dysfunction in humans. Diet supplemented with fresh red grapefruit positively influences serum lipid levels of all fractions, especially serum triglycerides, and also supports serum anti-oxidant activity (Gorinstein et al., 2006). In hypercholesterolemic children, the supplementation of mandarin juice to diet led to a decrease in the markers of oxidative stress and an increase in anti-oxidant activity (Codoñer-Franch et al., 2008). There are also clinical studies describing the positive effects of lemon juice on blood pressure (Adibelli et al., 2009) and orange juice on inflammatory markers such as high-sensitivity C-reactive protein or fibrinogen (Dalgard et al., 2009). In addition, when orange juice is added to the intake of a high-fat, high-carbohydrate meal, it prevents meal-induced oxidative and inflammatory stress (Ghanim et al., 2010).

Citrus fruit consumption and ischemic stroke
Stroke is defined as the damage to part of the brain caused by an interruption to its blood supply or leakage of blood outside of vessel walls. Stroke is the third leading cause of death in developed countries. There are two major types of stroke. The first, called ischemic stroke, is caused by a blood clot that blocks a blood vessel or artery in the brain. Approximately 80% of all strokes are ischemic. The second, known as hemorrhagic stroke, is caused by a broken blood vessel that leaks into the brain tissue. The consumption of citrus fruits and juices has been reported to be associated with a reduced risk of ischemic stroke (Mizrahi et al., 2009) as a function of their content of vitamin C and phytochemicals.

Citrus fruit consumption and cancers
Cancer is a major public health burden in the United States and in other developed countries. In a recent review on citrus fruit intake and cancer risk (Foschi et al., 2010) conducted on a series of case-control studies (including 955 patients with oral and pharyngeal cancer, 395 with esophageal cancer, 999 with stomach cancer, 3,634 with large bowel cancer, 527 with laryngeal cancer, 2,900 with breast cancer, 454 with endometrial cancer, 1,031 with ovarian cancer, 1,294 with prostate cancer, and 767 with renal cell cancer), it was shown that citrus fruits provide protection against cancers of the digestive and upper respiratory tract. This effect was significant even with moderate citrus fruit consumption (i.e., 1 to <4 portions/week). Several compounds can account for the observed protection. Among them, vitamin C and flavonoids can protect against oxidative damage, inhibiting the formation of carcinogens and protecting DNA from damage. Flavonoids also have anti-proliferative and anti-angiogenic effects. In addition, citrus pectin has also demonstrated anti-cancer activity, explained in part a) by its ability to block the carbohydrate-binding of galectin-3 necessary for the growth and metastasis of tumor cells (Bergman et al., 2010) and b) by its immunomodulatory potential (Salman et al., 2008).

Citrus fruit consumption and weight management
Obesity is a major health problem in the world today. An estimated 300 million people around the world are obese. The result of the continued energy imbalance has produced a high prevalence of overweight and obese adults and children (Flegal et al., 2010a). Obesity levels in some developed countries have doubled in recent years and are rising in developing countries as well. More dramatic is the increase in the prevalence of overweight children and adolescents of both sexes. In adults, 35.5 percent of women and 32.2 percent of men are obese (Flegal et al., 2010b). Up to 9.5 percent of infants and toddlers are at or above the 95th percentile of the weight-for-recumbent-length growth charts. Among children and adolescents ages 2 through 19 years, 11.9 percent are at or above the 97th percentile of the body mass index-for-age growth charts, 16.9 percent are at or above the 95th percentile, and 31.7 percent are at or above the 85th percentile. Among minorities, there is a higher prevalence of both overweight and obese children (International Obesity Taskforce, www.iotf.org). Replacing high energy density foods (high calories per weight of food) with lower energy density foods, such as fruits and vegetables, can be an important weight management strategy. At the same calorie level, foods such as fruits and vegetables with low energy density provide a greater volume of food, which helps people feel satiated at a meal while consuming fewer calories. The water and fiber present in citrus fruit increase the volume of foods and reduces their energy density. The inclusion of citrus fruits in a healthy diet helps promote satiety, reduce the intake of excessive calories, and promote effective weight management. Preliminary studies suggest that the inclusion of citrus fruits in one’s diet may play an important role in weight management.

Detailed studies with citrus fruits have been carried out. Dietary supplementation of Moro juice, a blood orange, significantly reduced body weight gain and fat accumulation (Titta et al., 2010). Effective anti-corpulence and anti-cancer compounds were isolated from the peel of citrus fruits. Bioactive components were identified as polymethoxyflavones and coumarin derivatives (Hirata et al., 2009). Citrus polymethoxyflavones induce adipocyte cell apoptosis mediated through Ca(2+) signaling. Loss of adipocytes reduces body fat and may help to maintain weight loss. These findings provide a rationale for evaluating the role of polymethoxyflavones in the prevention and treatment of
obesity (Sergeev et al., 2009). Peel or segment wall extract from Satsuma mandarin orange induced lipolysis in a concentration-dependent manner; extracts contained high concentrations of synephrine, an adrenergic amine (Tsujita et al., 2007). Citrus aurantium (bitter orange or sour orange) contains a number of phytochemicals of interest, including p-octopamine and synephrine alkaloids that are adrenergic agonists (Haaz et al., 2006), which increase energy loss. Consumption of lemon pectin, citric acid and related compounds reduces the risk of obesity through their effects on thermogenesis (González-Molina et al., 2010).

A major problem of obesity is its evolution into chronic diseases. Obesity has been linked to several serious medical conditions (including atherosclerosis, hypertension, diabetes and cancer) that shorten life spans and to other diseases (such as gallbladder disease, osteoarthritis, gout, and breathing problems) that produce disabilities. Oxidative stress is a link between obesity and inflammation potentially leading to the development of chronic diseases associated with obesity. Therefore, effective strategies require not only weight loss management but also the development of approaches that counteract the pathogenesis of co-morbidities. Components of citric fruits can play a major role in this sense. Mandarin juice consumption with a reduced calorie diet positively affected anti-oxidant activity and produced a decrease in biomarkers of oxidative stress in obese children (Codoñer-Franch et al., 2010). Orange juice shows anti-oxidant potential (Sánchez-Moreno et al., 2003) and reduces C-reactive protein concentrations (Devaraj et al., 2006). Half of a fresh grapefruit eaten before meals was associated with significant weight loss and an improvement in insulin resistance. (Fujioka et al., 2006)

CONCLUSION
In conclusion, citrus fruits are low in fat, low in energy density, and high in fiber, water and essential nutrients such as vitamin C and folate and minerals such as potassium. Citrus fruit also provide phytochemicals, which are active anti-oxidants (carotenoids and flavonoids) and are proven to counteract chronic diseases. In addition, citrus fruits and juices have more favorable overall nutrient-to-price ratios than many vegetables and fruits, which help the consumers to obtain foods which provide optimal nutrition at an affordable cost (Drewnowski, 2010).

REFERENCES


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