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Foods with Functional Properties and Their Potential Uses in Human Health

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Abstract

Vegetables and fruits have been a part of human diet since ancient times; nevertheless, as countries develop, its population's feeding habits change and tend to have a diet poor in vegetables and fruits, with well-known consequences. Several food plant products with massive consumption and within the reach of the population are products such as artichoke, leek, hot chili pepper, coriander, kiwifruit, sweet orange, highbush blueberry, and maracuyá to name a few. They have many beneficial properties principally by its content of phytochemicals with high impact on human health, beyond nutritional support. The phytochemicals are bioactive compounds such as vitamins, carotenoids, phenolic acid, and flavonoids, which contribute to antioxidant capacity and as a whole prevent chronic nontransmissible diseases such as: diabetes, high blood pressure, high cholesterol in blood, cardiovascular risks, among others. This relationship between food plant for human consumption and its impacts on human health is discussed in this chapter, highlighting coriander and kiwifruit by its wide range of benefits.

Keywords: phytochemicals, antioxidant capacity, polyphenols, chronic diseases, healthy feeding habits, life style

1. Introduction

Foods are neither inherently good nor bad. Rather, good or bad eating habits, as well as other factors such as smoking and physical activity, all influence human health. If we desire a healthy lifestyle and wish to avoid chronic nontransmissible disorders such as diabetes, high

levels of cholesterol, cardiovascular diseases, etc., foods, especially those that are functional, are only a part of the solution [1].

Despite a wealth of information, there is no universal definition about what constitutes a functional food. However, there is consensus concerning central concepts, which are associated with their benefit for human health beyond their traditional nutrients [2]. Along the same lines, the importance of phytochemicals as a class of biologically active metabolites in plants is accepted [3]. When discussing “potential use for human health” to refer to a particular plant, preliminary evidence on its outstanding phytochemical content must already exist, which means it can be used in the future as a source to investigate more profoundly its beneficial implications in human health.

Some processes such as cooking alter the content and composition of phytochemicals present in vegetables, reducing their concentrations by thermal degradation or augmenting their concentration with respect to the raw material. However, these effects are varying with the cooking method and type of phytochemical [4]. These, together with the growing consumption of fiber, are the principal reasons to recommend the regular intake of fresh vegetables [5].

Functional foods may be plant or animal products, that are fresh, semi-processed or processed, but in this chapter we will refer mainly to fresh plants and their properties beyond their nutritional characteristics. In addition, we will also discuss the existence of several common horticultural and fruit plants that are widely available and consumed by the human population, whose functional properties have yet to be systematized and categorized. Vegetables with high functional interest such as artichoke, leek, hot chili pepper, and coriander, as well as fruit plants such as kiwifruit, sweet orange, and highbush blueberry are considered [6–9]. Within the species discussed in this chapter, only artichokes must be consumed cooked, whilst the others may be eaten fresh.

We believe that the updated information about plants with characteristics as functional foods responds to a need of the population and scientists to learn more about healthy habits and how consumption of natural foods can improve their quality of life.

2. Horticultural species with functional properties and their potential use in human health

The properties and features of some horticultural species that have beneficial effects on human health are mentioned here. It is important to note that the artichoke, leek, hot chili pepper, and coriander are considered in this section, because these species are widely consumed by the human population.

2.1. Artichoke (*Cynara cardunculus* var. *scolymus* and *Cynara scolymus*)

These species belong to the *Asteraceae* family (**Figure 1**) are native to the Mediterranean region [10] and grow in many parts of the world [11]. *Cynara scolymus* is cultivated due to its large immature flower heads, which have special functional and nutraceutical characteristics, and a

high antioxidant capacity, with more than 9000 μmol trolox equivalents (TE) 100 g^{-1} FW [12]. This antioxidant capacity is due to its high content of total polyphenols like caffeoylquinic acids and flavonoids [7]. These polyphenols are present in flower heads, with values ranging from 4.8 to 29.8 mg g^{-1} FW in different Italian varieties [7, 13, 14]. It is important to mention that these values are not only dependent on the genetic background, as the interaction genotype-environment also has an influence [7]. Therefore, antioxidant content may be affected by agricultural practices, because in different locations, the same variety may have different antioxidant capacities.



Figure 1. Immature flower head of artichoke.

Choleretic and hypocholesterolemic activities, due to the presence of chlorogenic acid, cynarin, and lutein, have been reported in clinical studies, which demonstrated the effect of leaf extracts on the inhibition of the biosynthesis of cholesterol in rat hepatocytes [15]. Furthermore, these extracts prevented necrosis in rat hepatocytes provoked by hydroperoxides indicated for treatment of dyspepsia, or dyskinesia of the bile ducts, as well as disorders in the assimilation of fats in humans [16–18]. The nutraceutical and therapeutic actions of several metabolites are summarized in **Table 1**. The positive effects of ingesting *C. cardunculus* flower heads have been widely demonstrated; nevertheless, artichoke leaves and external parts of bracts may be used in industrial processes to obtain functional metabolites for use in human health.

Species	Molecule	Part of plant	Specific function for human health	References
<i>Cynara cardunculus</i> L. var. <i>scolymus</i> L. / <i>Cynara scolymus</i>	Caffeoylquinic acids, flavonoids, and cynarin	Flower head and leaves	Antioxidant capacity	[7, 12–14]
	Chlorogenic acid and cynarin	Flower head and leaves	Choleretic, hepatoprotective	[168, 169, 170]
	Luteolin	Flower head and leaves	Hypocholesterolemic	[171]
	Inulin	Flower head, stem and leaves	Stimulates the intestinal flora, hypocholesterolemic	[170]
<i>Allium ampeloprasum</i> Var. <i>porrum</i> / <i>Allium porrum</i>	Polyphenols	White part and green leaves	Antioxidant capacity	[28]
	Ascorbate	White part and green leaves	Growth and tissue repair, antioxidant	[28, 30]
	Steroidal saponines	White part	Antiinflammatory, gastroprotective and antiulcerogenesis	[31, 32]
	Methanolic extracts	White part and green leaves	Antimicrobial	[35]
	Steroidal saponines/polyphenols	White part	Cytotoxic activity: a potential anticancer agent	[33, 35]
	Hydroalcoholic extracts	White part and green leaves	Hypolipidemic/hypocholesterolemic	[172, 173]
<i>Capsicum annuum</i> L.	Polyphenols	Fruit	Antioxidant capacity	[37, 174]
	Dietary fiber	Fruit	Anticarcinogenic, prevents diabetes, hypocholesterolemic	[9, 175]
<i>Coriandrum sativum</i> L.	Essential oil, aqueous, methanolic and ethanolic extracts	Fruit and leaves	Prevention of several chronic degenerative disorders	[8, 44, 48]
	Essential oils	Fruit and leaves	Anticancer activity	[176, 177]
	Extracts	Seeds	Hypocholesterolemic	[51]
	Extracts	Seeds	Antidiabetic	[49]
	Diethyl ether and aqueous extracts	Fruit, seeds and leaves	Anxiolytic, sedatives, antidepressant	[51, 54, 56]
	Aqueous, ethanolic and chloroformic extracts	Aerial parts	Analgesic	[55]
	Ethanolic extract	Root	Antimicrobial	[48]
	Extracts	Aerial parts	Antioxidant activity	[47]
	Hydroalcoholic extract	Aerial parts	Anticonvulsant	[15]
	Ethanolic extract	Seeds	Cognitive effects (improves learning in the long term)	[53]

Table 1. Selected plant species and their compounds that are beneficial for human health.

Inositol and inulin are soluble carbohydrates, which are present in external bracts of artichokes. In the case of inositol (chiro-scyllo- and myo-inositol), values fluctuate from 6.7 to 9.3 mg g⁻¹ DW while for inulin they fluctuate from 69.8 to 114.6 mg g⁻¹ DW [16]. These values are higher than the ones reported by Hernández-Hernández et al. [17] in edible bracts of artichoke. Regarding the beneficial properties, inositols have been used in treatments against diabetes mellitus [18]. In this sense, Crawford et al. [19] reported that inositol prevents diabetes mellitus in pregnant women and concluded that myo-inositol shows promising results by preventing the onset of the disease. Furthermore, inulin has been associated with some beneficial functional properties, as it can be a good source of carbohydrates and fiber, associated with positive effects in the prevention of colon cancer [20, 21]. In addition, prebiotic properties and effects on the absorption of calcium have been reported [20, 21]. In this sense, research on mineral absorption of calcium and magnesium concluded that inulin can reduce risk for osteoporosis by increasing their absorption [22].

2.2. Leek (*Allium ampeloprasum* var. *porrum* or *Allium porrum*)

It has been reported that this species has a substantial nutraceutical and functional properties (see **Table 1**) and is cultivated in Asia, America, and Europe, especially in the Mediterranean region [23, 24]. *A. ampeloprasum*, belongs to subgenus *Allium* section *Allium* (**Figure 2**), is considered a "complex species" due to different ploidy levels and genome constitution, and diploid, tetraploid, and octoploid accessions have been described [25, 26]. In fact, Hirschegger et al. [27] suggested that molecular evidence could be used to consider this species as a tetraploid horticultural group together with other *Allium* genus species. This condition is particularly important in accounting for its nutritional, functional, and nutraceutical characteristics [28].



Figure 2. Green leaves and white part of leek.

The principal beneficial properties of the *Allium* genus are mainly due to the presence of many sulfur compounds containing bioactive constituents, including: dimethyl disulfide, methyl propenyl disulfide, propyl propenyl disulfide, dimethyl trisulfide, methyl propyl trisulfide, methyl propenyltrisulfide, S-methyl cysteine sulfoxide, S-propyl cysteine sulfoxide, S-propenyl cysteine sulfoxide, and N-(γ -glutamyl)-S-(E-1-propenyl) cysteine [6].

In the evaluation of 30 leek cultivars, the content of total phenols varied from 5 to 15 mg gallic acid equivalents (GAE) g^{-1} DW for whole plants [28]. Other studies reported values of 5.5–6.0 mg GAE g^{-1} DW in whole leeks [29]. These differences in the total phenolic content could be attributed to the genetic variability of this species and agricultural systems [28]. Moreover, in the same study, the oxygen radical absorbance capacity (ORAC) was evaluated, where the green leaves possessed 82–135 $\mu\text{mol TE g}^{-1}$ DW, whereas the white part contained just 27–88 $\mu\text{mol TE g}^{-1}$ DW. Additionally, Vandekinderen et al. [30] determined the total vitamin C content (ascorbic acid + dehydroascorbic acid) whose values reached 9.65 mg 100 g^{-1} FW in whole leeks. Bernaert et al. [28] reported 5.54 mg ascorbic acid (AA) g^{-1} DW in whole leeks and higher values in green leaves than in white parts (2.77–8.52 mg AA g^{-1} DW and 0.89–3.55 mg AA g^{-1} DW, respectively). Values of polyphenols, AA, and antioxidant activity may be influenced by the season of year, genetic characteristics, and biotic and abiotic factors during vegetative growth, as well as agricultural practices.

The antiinflammatory, gastroprotective, and cytotoxic activities of organosulfate compounds, saponins, particularly steroidal saponines, have been well documented in *A. ampeloprasum* var. *porrum* [31–33].

Another property that is exclusive to the *Allium* genus is their antimicrobial activity (see **Table 1**). This has been reported since ancient times, and leeks have been used to treat wounds and respiratory diseases, as well as acting as an antibacterial agent due to the presence of alliin-containing structures [34, 35]. Polyphenols of methanolic extracts of green leaves and white parts of *A. porrum* are potent against Gram-positive (*Staphylococcus aureus* ATCC 25923 and *Bacillus subtilis* ATCC 6633) and Gram-negative (*Klebsiella pneumoniae* ATCC 13883, *E. coli* ATCC 25922, *Proteus vulgaris* ATCC 13315 and *Proteus mirabilis* ATCC 14153) bacteria, as well as fungal species (*Candida albicans* ATCC 10231 and *Aspergillus niger* ATCC 16404) [28]. These authors affirm a negative effect of methanolic extracts of *A. porrum* on Hep2c, L2OB, and RD cell cultures. This cytotoxic activity could indicate a future use of these natural biological compounds in human health.

2.3. Hot chili pepper (*Capsicum annuum* L. var. *longum*)

The fruit of this species (**Figure 3**), immature or mature and leaves, contains at least two groups of bioactive compounds of significance for human health, polyphenols and carotenoids. The polyphenol content is variable but reaches over 20 mg GAE g^{-1} DW in mature and dried fruits [36], and 40 mg GAE g^{-1} DW in leaves [37]. The polyphenols of fruits have a total antioxidant capacity of 26.6–44.4 $\mu\text{mol TE g}^{-1}$ DW, depending on the variety [36].

According to Serrano et al. [38], the small intestine has around 25% of bioavailability of total polyphenols.



Figure 3. Immature fruit of red hot chili pepper.

Regarding the total carotenoids present in different varieties of red hot chili peppers, Hervert-Hernández et al. [36] indicated values from 87.6 to 373.3 mg 100 g⁻¹ DW. In addition, the same authors determined that the bioavailability of chili carotenoids in the small intestine ranges from 20 to 50% of the total content, depending on the variety [36]. In addition, *C. annuum* is also a good source of vitamin C (up to 26.5 mg g⁻¹ DW) [39]. Minerals, mainly potassium and magnesium, as well as dietary fiber, reducing sugars (around 20% DW), and antimicrobial activity useful for functional food production are also characteristic of this species [9]. Regarding the antimicrobial activity, De et al. [40] identified three pathogens that are susceptible to ethyl alcohol extracts of chili: *Bacillus subtilis* ATCC6633 (minimum inhibitory concentration (MIC) 10–25 mg mL⁻¹), *Escherichia coli* ATCC10536 (MIC 25–50% mg mL⁻¹), and *Saccharomyces cerevisiae* ATCC 9763 (MIC 2–5% mg mL⁻¹). In addition, an antimicrobial activity in *Staphylococcus aureus* ATCC14154, *Escherichia coli* ATCC-1698, *Pseudomonas aeruginosa* ATCC-23993, *Candida albicans* ATCC-14053, and *Sarcina lutea* (Collection of Microbiology Laboratory of Chemical Engineering Department, Institut Teknologi Bandung) has also been reported using ethanolic extracts of chili [41]. These authors indicate that capsaicin may be one of the main responsables of microorganism inhibition. Likewise, Huang et al. [42] affirm that developments of *Staphylococcus aureus*, *Saccharomyces cerevisiae*, and *Aspergillus niger* were negatively affected by capsaicin.

2.4. Coriander (*Coriandrum sativum* L.)

This species of the *Apiaceae* family (**Figure 4**) is usually cultivated throughout the year in diverse edafoclimatic areas [43]. It is native to Italy and is currently propagated in several Mediterranean regions of Europe, as well as in America and Asia [44]. It is consumed principally fresh, either alone or in salads. This species has multiple human health benefits and has considerable potential as a functional horticulture species (see **Table 1**). *C. sativum* contains essential oils in seeds and in the pericarp whose content and composition appear to be dependent on biological and geographical traits [35]. The oil content is approximately 1% of seed weight of which linalool is the major component (73%) [44–46]. In the stem and immature leaves, the most important compounds are essential oils, flavonoids (quercetin, kaempferol, and acacetin), phenolic acids (vanillic acid, p-coumaric acid, syringic acid, p-OH benzoic acid, cis-ferulic acid, and trans-ferulic acid), and polyphenols [8]. The principal phytochemicals are β -carotene ($5.1 \text{ mg g}^{-1} \text{ DW}$), AA ($1.16 \text{ mg } 100 \text{ g}^{-1} \text{ FW}$), total phenolics ($2.05 \text{ mg GAE } 100 \text{ g}^{-1} \text{ DW}$), and antioxidants ($1.12 \text{ mg GAE } 100 \text{ g}^{-1} \text{ DW}$) [47].



Figure 4. Stem and immature leaves of coriander.

According to Kumar et al. [48], ethanolic extracts of fresh coriander roots contain alkaloids, flavonoids, terpenoids, sterols, carbohydrates, saponins, and phenolic compounds. This extract and its fractions possess significant antibiotic activity against *Staphylococcus aureus*, *Bacillus cereus*, *Salmonella typhi*, and *Klebsiella*.

The antihyperglycemic (antidiabetic) activity of coriander has been studied by several authors. Deepa and Anuradha [49] analyzed the effects of coriander seed extracts in rats, which showed decreases by 44% in blood glucose and by 58% in glycosylated hemoglobin levels with respect to untreated rats. At the same time, the insulin level in plasma increased to 40%. They also reported beneficial effects in kidney and pancreas. Moreover, *C. sativum* seeds have hypocholesterolemic properties in rats, increasing hydroxymethyl glutaryl CoA (HMG-CoA) reductase and plasma lecithin cholesterol acyl transferase activities [50, 51].

Additional properties such as analgesic, anticonvulsive, anxiolytic, sedative, antidepressant, and cognitive effects of coriander have been tested *in vivo* in mice. In many cases, its effect was comparable with equivalent standardized doses of the typical drugs used to treat these diseases, elegantly demonstrating the beneficial properties of coriander in human health [15, 52–56].

3. Fruit species with functional properties and their potential use in human health

Fruits, in addition to horticultural species, constitute a group of foods for humans with important functional characteristics. In this chapter, we consider kiwifruit, sweet orange, and high-bush blueberry given their extensive geographical distribution, consumption, and richness in biocompounds with nutraceutical properties.

3.1. Kiwifruit (*Actinidia deliciosa* [A. Chev] C.F Liang et A.R Ferguson/*Actinidia chinensis* [Planch])

This species originated in Asia [56] and belongs to the *Actinidiaceae* family (**Figure 5**). The *Actinidia* genus includes 66 species, but only four are cultivated for fruit production. Of these, *A. deliciosa* and *A. chinensis* are the most accepted by consumers worldwide [58, 59]. Here, we will refer to both species indistinctly. Kiwifruits have multiple sensory, nutritional, and phytochemical properties and are rich in dietary fiber, acids, phenols, and vitamins [57, 60] (see **Table 2**). These contribute to antioxidant activity, which varies with the variety and the part of fruit consumed. For example, Soquetta et al. [57] found higher values of antioxidant activity measured by the ferric reducing ability of the plasma (FRAP) method as well as carotenoids, flavonoids, and vitamin C in flour of the Monty variety compared to the Bruno variety. Moreover, the same authors found the highest content of these compounds in flours from kiwifruit skin compared to flour from kiwi fruit bagasse, reporting values from 59 to 189 mg AA in 100 g of kiwifruit flour, almost double that found in oranges and strawberries [61], and 200–1200 mg GAE 100 g⁻¹ for phenolic compounds. D'Evoli et al. [60] indicated that in the total fresh kiwifruit, the content of oxalic acid was 8 mg 100 g⁻¹ FW, while citric and malic acid contents were 1.2 and 0.24 g 100 g⁻¹ FW, respectively. Furthermore, the same authors indicated that kiwifruits contain 90 mg GAE 100 g⁻¹ FW of the total polyphenols, 0.2 mg 100 g⁻¹ FW of lutein, and 0.06 mg 100 g⁻¹ FW of β -carotene, in addition to α -tocopherol, γ -tocopherol, and γ -tocotrienol which represent 0.9, 0.04, and 0.12 mg 100 g⁻¹ FW, respectively. All these compounds give kiwifruit

strong antioxidant properties that contribute to protect cells against oxidative damage [62]. Its antioxidant capacity (ORAC) varies from 0.06 to 1.4 $\mu\text{mol TE } 100 \text{ g}^{-1} \text{ FW}$ of fruit, depending on the hydrophilic or lipophilic fraction used in the analysis [60]. Lee et al. [63], using the same method but expressed as vitamin C equivalents (VCE), reported values from 595.7 to 2662.7 VCE $100 \text{ g}^{-1} \text{ FW}$. Clinical studies indicate that the uptake of vitamin C derived from kiwifruit reaches 40% in humans, similar to the rate of synthetic vitamin C uptake [64, 65]. This was tested by Vissers et al. [66] in a mouse model, where they found highly effective delivery to tissues. Together with vitamin C uptake, several other nutrients and beneficial phytochemicals are consumed, with synergistic effects, among them, of iron (Fe). A clinical study with women [67, 68] indicated that a breakfast fortified with Fe, when consumed with kiwifruit, can improve Fe content in women with low Fe stores; this may be related with the high values of AA, lutein, and zeaxanthin of kiwifruit.



Figure 5. Fruits of *Actinidia deliciosa* commonly name kiwifruit.

The dietary fiber content of kiwifruit is 2–3.39 g $100 \text{ g}^{-1} \text{ FW}$ [60, 69] of which 25–30% is found in the flour skin and fruit bagasse [57]. These values are higher than several of the widely consumed fruits such as orange, apple, banana, strawberries, and blueberries [61]. Thus, kiwifruits contain sufficient fiber thus improving digestive performance, ameliorating digestive transit, alleviating constipation, and irritable bowel syndrome [60, 70–72]. Studies performed in rat have reported that kiwifruits improve digestion of the principal proteins of beef muscle, soy protein, gelatin, and gluten [73]. This is related with its content of actinidin, a very active proteolytic enzyme, which acts in concert with the gastric and intestinal proteases, pepsin, and pancreatin, generating an increment in protein digestion in the gastric and intestinal tracts [74, 75].

Species	Molecule	Part of plant	Specific function for human health	References
<i>Actinidia deliciosa</i> (A. Chev) C.F. Liang et A.R. Ferguson/ <i>actidinia chinensis</i> Planch.	Dietary fiber	Fruit and flour skin and bagasse of fruit	Alleviate constipation/laxative	[57, 60, 71]
	Actinidin	Whole fruit	Increment on protein digestion	[73 – 75]
	Polyphenols, flavonoids Vitamin C, E, lutein, zeaxanthin and other phytochemicals	Fruit and flour skin and bagasse of fruit	Antioxidant activity/ reduces cellular damage from oxidative stress	[57, 62, 71, 86]
	Vitamin C	Fruit	Positive synergic effect with nutrients and phytochemicals	[61]
	Essential amino acids, linolenic acid, folic acid, vitamins A, B6, B12, C, and E, minerals like Zn, Cu, Fe, and Se.	Fruit	Strengthen the immune system	[82, 84]
	Phytosterols and ursolic acid/independent or synergic actions of polyphenols, vitamin C, and E	Fruit	Improve lipid profile in men/reduction of risk of cardiovascular diseases	[61, 76, 77, 79, 86]
	Unidentified	Fruit	Antihypertensive	[79, 80]
	Unidentified	Fruit	Antithrombotic	[78]
	Vitamin C and inositol and other unidentified compounds	Fruit	Antiinflammatory activities	[71, 178]
	Phytosterols and ursolic acid	Fruit	Inhibit carcinogenesis processes	[86]
<i>Citrus sinensis</i> (L.) Osbeck	Fiber	Fruit	Antiirritable bowel syndrome	[72]
	Unidentified	Juice and ethanolic peel extract	Antihyperglycemic activity	[89, 104, 105]
	Flavonoids and other polyphenols	Juice	Antihypercholesterolemic activity	[107, 110, 111]
	Flavonoids other than anthocyanins	Juice	Antithrombotic	[112]
	Flavonoids and other polyphenols	Juice	Cardioprotective	[108, 111]
	Flavones	Juice	Enhanced antioxidant defense system	[114]

Species	Molecule	Part of plant	Specific function for human health	References
<i>Vaccinium corymbosum</i> L.	Unidentified	Juice	Antiinflammatory activity	[119, 120]
	Flavones, flavonoids and flavonols	Juice	Microbial activity	[101, 122]
	Unidentified	Juice	Hypoglycemic activity	[135]
	Unidentified	Juice	Antiinflammatory	[140]
	Interaction phenolic compounds	Fruit and leaf aqueous extract	Antimicrobial	[138]
	Anthocyanins and other phytochemicals	Fruit	Modulation of vascular function	[178, 179]
	Anthocyanins and other polyphenols	Extract hydroalcoholic of fruit	Cytotoxic activity	[142]
	Antioxidant action	Fruit	Antiatherogenic effect/hypocholesterolemic	[144]

Table 2. Selected fruit species and their compounds that are beneficial for human health.

Kiwifruits possess hypocholesterolaemic activity in hypercholesterolemic men [61]. This property may be related with the expression of the *Taq1B* gene in response to the consumption of kiwifruits, which modulates the content of lipids in blood plasma and has been associated with a reduced risk of cardiovascular diseases [76, 77]. However, other researchers did not find the same effect on cholesterol levels, but concluded that the consumption of two or three fruits per day can reduce levels of blood triglycerides by 15%, compared with the control [78]. Similar clinical studies have demonstrated that kiwifruits (two or three per day) can reduce blood pressure in male smokers [79], possibly related with 11% reduction in angiotensin-converting enzyme (ACE) activity. This finding is considered relevant because it is very difficult to modulate hypertension by diet [79, 80]. In addition, a clinical study revealed that daily consumption of kiwifruit produces a reduction of 15% in platelet aggregation, which can be understood as antithrombotic activity [79, 81]. Nonetheless, Brevik et al. [81] discussed this effect because it may be influenced for the rate of kiwifruit consumption.

Additionally, Hunter et al. [82] and Skinner [83] affirm that kiwifruits have an important function in the modulation of the immune system. In this context, Hunter et al. [62] indicate that kiwifruit contribute significantly to lessening upper respiratory tract infections, head congestion, and sore throats in older individuals. Even though, there is a large source of variation in immune function, the nutrient status of this fruit is crucial. The most important phytochemicals present in kiwifruit include essential amino acids, linolenic acid, folic acid, vitamins A, B6, B12, C, and E, and minerals such as zinc, copper, iron, and selenium [84]. Given the type and content of phytochemicals, beneficial immune effects are not unexpected [82], although the mechanisms and the specific molecules underlying these effects are unknown. Moreover,

preliminary studies under *in vitro* and *ex vivo* conditions found a protective effect of kiwifruit over oxidative damage of DNA, which may be interpreted as inhibition of the carcinogenesis process [85, 86]. Subsequently, Collins et al. [87] determined that kiwifruit consumption could protect against oxidative DNA damage protection in humans and *ex vivo* by both increasing the antioxidant status in the plasma, and stimulating DNA repair.

3.2. Sweet orange (*Citrus sinensis* (L.) Osbeck.)

The sweet orange is one of most economically important fruits in worldwide [88, 89]. It is believed that the *Citrus* genus is native to Asia, specifically from Southern China (Yunnan), which may be the origin and point of distribution of several contemporaneous *Citrus* species [90]. *Citrus sinensis* (L.) Osbeck belongs to the *Rutaceae* family and is believed to be a backcross hybrid between pummelo and mandarin (**Figure 6**) [91, 92]. The sweet orange species have several cultivated varieties, some of which are mentioned by Grosso et al. [93], but in this chapter we will discuss this species without distinguishing between varieties.



Figure 6. Fruits of *Citrus sinensis* commonly name sweet orange.

The sweet orange harbors several interesting phytochemical compounds that play an important role in human health (see **Table 2**). These include vitamins and polyphenols such as hesperidin, gallic acid, sinapic acid, caffeic acid, p-hydroxybenzoic acid, vanillic acid, narirutin,

naringin, p-cumaric, and ferulic acid [93–96]. Hesperidin is the major polyphenol of sweet oranges, accounting for over 77% of the flavonol content [98–100]. These compounds are present in the edible fruit, juice, and/or peel, and here we concentrate on the juice and the edible fresh fruit, due to their direct implications in human health. As a functional food, Letaief et al. [97] determined that the AA content in orange juice fluctuates from 551 to 614 mg L⁻¹, total phenolics range from 413 to 417 mg GAE L⁻¹, and flavonoids from 25 to 60 mg catechin equivalents (CE) g⁻¹ DW. Roussos [94] measured total phenols (964–1215 mg TAE L⁻¹). The percentage of antioxidant activity of the juice, evaluated by the DPPH method, fluctuated from 36.4% to 56.6% [94, 97]. The antioxidant activity of sweet orange juice is dependent on the state of maturity of the fruit. Indeed, Adu et al. [101] noted higher levels of antioxidant activity in fruits of 3–6 months (over 80%) than in fruits of 10–12 months (around 70%). Fiber and amino acids are also important in juice. In this sense, Aschoff et al. [96] informed 1.4 g 100 g⁻¹ of dietary fiber, and Roussos [94] mentioned that juice contains 18 amino acids (included the essentials amino acids), especially proline, arginine, asparagine, glycine, serine, and γ -aminobutyric acid. Other authors have determined some of these and other phytochemicals in homogenate orange segments without peel, where Aschoff et al. [96] reported 36.2 mg 100 g⁻¹ FW of AA, 271.5 μ g 100 g⁻¹ FW of carotenoids, and 13.6 g 100 g⁻¹ FW of dietary fiber. Recently, Molan et al. [102] evaluated some compounds and properties of sweet orange seeds, such as total polyphenols (10.9–39.4 mg GAE g⁻¹ DW) and antioxidant activity (around 50%) by the DPPH method.

It has been reported that to maintain sufficient antioxidant protection, an estimated average consumption of 60 and 75 mg d⁻¹ of vitamin C is required for young women and men, respectively; however, it is suggested an increase of 35 mg d⁻¹ for smokers [103]. This is important because orange consumption provides other phytochemicals with multiple benefits to human health. Several clinical studies confirm this assertion. For example, sweet orange juice also harbors antidiabetic activity, as determined in rats by metabolome analysis [104]. This agrees with research performed by Kumar and Bhaskar [105] in rats, using ethanolic orange peel extract, where blood glucose decreased around 60% with respect to the control after 3 weeks of treatment, similar to the drug, glibenclamide. Furthermore, Mallick and Khan [89] suggest a combination of juice of *C. sinensis* and *C. paradisi* in order to reduce the level of glucose and improve the insulin level in the plasma of diabetic rats.

Hypocholesterolemic activity was demonstrated in women with aerobic exercise and a consumption of 500 mL of sweet orange juice daily [106]. These authors found a 15% decrease of low-density lipoprotein (LDL-C) in serum and an 18% increase of high-density lipoprotein (HDL-L), whereas the ratio LDL/HDL-cholesterol decreased by 27%. Furthermore, they also noted an improved performance during physical activity, by a reduction of blood lactate. Moreover, a long-term study (twelve months) showed that consumption of orange juice (480 mL daily) triggered reductions of 11% in total cholesterol, 18% in LDL-cholesterol, 12% in apolipoprotein B, and 12% in the LDL/HDL ratio in comparison to nonconsumers [107]. In addition, an increase in antiatherogenic activity levels with the consumption of sweet orange juice was found [108–110]. Recently, it was informed that in rats, antihyperlipidemic activity is due to phytochemical compounds like flavonoids and other polyphenols with antioxidant capacity present in the juice of sweet oranges [111]. Therefore, the juice of sweet oranges may play an important cardioprotective role by preventing thrombosis [111]. In humans, orange

juice intake also decreases procoagulant activity, possibly due to flavonoids, like anthocyanins, or other juice components [112].

Another feature of sweet orange juice that supports its cardioprotective role is its effect on diastolic blood pressure, which was significantly lower in men after the daily consumption of 500 mL orange juice for 4 weeks, and an enhancement of endothelium-dependent microvascular reactivity [113]. These authors also suggest that hesperidin could be related to the beneficial effect of orange juice in cardioprotection. Likewise, Rangel-Huerta et al. [114] related the reduction of blood pressure in obese adults with the consumption of at least 300 mg flavanones over 12 weeks. On the contrary, Schär et al. [115] found a relatively high flavanone and phenolic metabolite content in plasma, but no effects were observed on blood pressure and cardiovascular risk biomarkers. Additionally, Giordano et al. [116] reported that a daily intake of 1 L of orange juice for 4 weeks was not effective in reducing cellular markers associated with cardiovascular risks. Nevertheless, in general, more evidence of positive rather than neutral or negative effects on cardiovascular risk of sweet orange juice consumption exists. In fact, risk factors are mainly associated with metabolic syndromes such as cholesterol, blood pressure, and blood coagulation, and frequent intake of orange juice may be a useful delaying strategy [117].

The antiinflammatory activity of sweet orange juice has been reported by Mohanty et al. [118] where glucose induced an acute increase in ROS and inflammation, and orange juice intake prevented meal-induced oxidative and inflammatory stress [119]. Recent studies in rats revealed the positive effect of orange juice over histological and biochemical changes related with a progress in colonic oxidative status [120]. Besides, the antimicrobial activity of sweet orange juice has been reported by several authors. Recently, Adu et al. [101] indicated an inhibitory effect of orange juice from fruits at different stages of development against Gram-positive and Gram-negative bacteria and fungi, like *B. subtilis* NCTC 10073, *C. albicans* ATCC 10231, *E. coli* ATCC 25922, *P. vulgaris* NCTC 4175, *Pseudomonas aeruginosa* ATCC 27853, and *S. aureus* ATCC. Similar results on bacteria and fungi were found by Javed et al. [121] using essential oils of orange peel. This positive effect appears to be related with flavones, flavonoids, and flavonols [122].

3.3. Highbush blueberry (*Vaccinium corymbosum* L.)

The highbush blueberry is a species that belongs to the *Ericaceae* family (**Figure 7**) [123] exhibiting a high level of morphological diversity [124]. It is native to eastern United States and was domesticated during the twentieth century [125, 126]. Its distribution and consumption is extensive due to the human health benefits (antioxidant and mineral characteristics) of fruits and leaves [123] (see **Table 2**). This fruit has a wide range of phenolic compounds, especially flavonols, such as quercetin, as well as anthocyanins [127]. Some values of the main phytochemicals that contribute to antioxidant capacity are: phenolic compounds (261–585 mg g⁻¹ FW), flavonoids (50 mg g⁻¹ FW), and anthocyanins (25–495 mg g⁻¹ FW) [128–130].

The antioxidant activity is higher in wild blueberry species, and part of this activity is conserved in cultivated varieties [131]. The total antioxidant activity of blueberry species ranges from 15.88 to 18.41 μmol Fe²⁺ kg⁻¹ FW, using the FRAP reagent [130]. Contreras et al. [132] showed values near to 80% of antioxidant capacity measured by the DPPH method under *in vitro* conditions. The same authors affirmed that antioxidant capacity is related with the content of chlorogenic acid, myricetin, syringic acid, and rutin.



Figure 7. Fruits of *Vaccinium corymbosum* commonly name highbush blueberry.

Plasma antioxidant capacity (PAC) is considered a biomarker for antioxidant status of humans. In this context, Fernández-Panchon et al. [129] indicated that PAC increased following consumption of some foods rich in phenols, which could be related with *in vivo* bioactivity, and its consequent positive effects for human health. More specific biological properties of blueberry have been described, such as anticarcinogenic, antidiabetic, antiinflammatory, antimicrobial, and reducing cholesterol, among other activities [133–135]. The hypoglycemic activity of blueberry is mentioned by several authors. Aktan et al. [135] reported a severe case of hypoglycemia in a patient of 75 years old, who had diagnosed but untreated prediabetes. Just before the episode, this patient consumed about 500 mL juice of blueberry and *Laurocerasus officinalis*, which is also considered hypoglycemic. Similarly, Cheplick et al. [136] affirmed from *in vitro* studies that blueberry fruit has potential for diet-based management of hyperglycemia, especially in the early stages of disease.

Blueberry extracts also have antimicrobial activity, which have interest considering that many microorganisms are pathogenic to humans. In this line, a significant effect of extracts on *Listeria monocytogenes* and *Salmonella enteritidis* was found under laboratory conditions by Shen et al. [137]. In the same conditions (laboratory), other extracts from dried fruits and leaves were tested on contaminant/pathogenic microorganisms. The findings indicate good results in the inhibition of development of *S. aureus* ATCC 29213, *Enterococcus faecalis* ATCC 29212, *E. coli* ATCC 27853, *K. pneumoniae* ATCC10031, *Acetobacter baumannii* ATCC 19609, *S. enteritidis* ATCC 3076, *Salmonella typhimurium* KCCM 11862, *Enterococcus faecium* LGM 11423, *Listeria innocua* NCTC 11286, *Bacillus cereu* ATCC 11778, and *P. aeruginosa* ATCC 27853 [134, 138, 139].

Zhong et al. [140] tested homogenized fresh blueberry juice as a therapy of juvenile idiopathic arthritis. The combined therapy of blueberry juice and etanercept (the typical drug used to treat this condition), improved the therapeutic effect of etanercept in patients with this pathology. Samad et al. [141] confirmed the antiinflammatory activity of extracts of blueberry in an *in vitro* study.

Yi et al. [133] studied the effect of phenolic compounds over colon cancer cell proliferation. Results indicated that these phytochemicals could inhibit the carcinogenic cells. Massarotto

et al. [142] demonstrated that anthocyanins and other phenolic compounds have cytotoxic activity, as tested in tumoral cell lines under *in vitro* conditions; thus, blueberry extracts could be useful for future treatment of cancer, as a natural cytotoxic agent. In this context, Tsuda et al. [143] obtained similar results with human leukemia cells and ethanolic extracts of several berries that include blueberry fruits. In all cases, the induction of apoptosis in the cancerous cells may be the mechanism triggered by blueberry.

The antilipidemic and antiatherogenic actions of blueberry have been reported by several authors. Coban et al. [144] indicated that the fresh fruit is food supplements that generate a positive effect over aorta and liver of hypercholesterolemic Guinea pigs [144]. In this respect, Cutler et al. [145] confirmed that berries are a special source of phytochemicals (anthocyanins and other phenolic compounds) and can be exploited as natural phytochemicals to contribute toward the amelioration of several chronic diseases, including those derived from alterations in the lipid profile in vascular systems.

3.4. Maracuyá (*Passiflora edulis* Sims)

Maracuyá (*Passiflora edulis* Sims) is a species that belongs to the *Passifloraceae* family (**Figure 8**) [146, 147] which is native to Brazil, South America. Nevertheless, some authors report that its real origin is Australia and is called *Passiflora edulis* forma *flavicarpa* [148, 149]. Variability studies have been carried out in South America, mainly in Colombia, as this region is particularly rich in this genus, although a low variability has been reported [150, 151]. Both scientific names *Passiflora edulis* Sims and *Passiflora edulis* forma are indistinctly considered in this chapter. Talcott et al. [152] identified several phenolic acids such as galacturonic acid, p-hydroxybenzoic acid, syringic acid, caffeic acid, p-coumaric acid, tryptophan, flavonoid glycoside, sinapic acid, ferulic acid, o-coumaric acid, and syringic acid in this species. Some compounds such as tryptophan, sinapic acid, and p-coumaric acid are in higher quantity with 733, 626, and 623 $\mu\text{g L}^{-1}$ DW, respectively. Within the latter, total phenolic compounds fluctuated from 342.8 to 382 mg GAE L^{-1} FW [153]; total carotenoids varied between 22.4 and 29.1 mg L^{-1} DW, and the ascorbic acid content from 0.22 to 0.33 g kg^{-1} FW [152, 153]. The anthocyanin concentration in pulps and by product, on the other hand, were 3.48 and 3.7 mg 100 g^{-1} DW, respectively, while the flavonoids in pulps and by product were 60.3 and 40 mg 100 g^{-1} DW, respectively [154]. Regarding the above, Zucolotto et al. [155] indicated that C-glycosyl flavonoids are present in several species of *Passiflora* in South America. Furthermore, Da Silva et al. [154] informed that values for β -carotene fluctuated from 57.93 to 1362.07 $\mu\text{g } 100 \text{ g}^{-1}$ DW for both pulp and by product. It is worth noting, that piceatannol, a compound with an important antioxidant characteristic, is present in peel and seeds of the maracuyá fruit [156]. Moreover, the total antioxidant activity was found to reach values from 409.13 to 805.5 $\mu\text{M TE L}^{-1}$ FW in this fruit [153], while Marcoris et al. [157] indicate values ranging from 1279 to 1460 $\mu\text{M TE L}^{-1}$ FW. Total dietary and soluble fiber is another important characteristic attributed to this species, with values fluctuating from 35.5 to 81.5 g 100 g^{-1} DM. These values are higher in comparison to other tropical fruits such as *Mangifera indica*, *Ananas comosus*, and *Psidium guajava* [158]. The maracuyá fruit has several special characteristics that are beneficial for human health, described in **Table 2**. Within the latter, the most important properties are the sedative

and anxiolytic activities, which are common to several other species of the *Passiflora* genus [159]. Evaluation of aqueous extracts of pericarp fruit on rats concluded that a sedative effect was obtained with an oral administration of 300 mg kg^{-1} [160]. This effect was corroborated by a dose-dependent decrease of the locomotor-activity. Similar studies using ethanolic extracts of maracuyá leaves in rats exhibited sedative effects at 400 mg kg^{-1} [161]. Figueiredo et al. [162] reported that 130 mg kg^{-1} of bark flour of maracuyá fruits showed a sedative effect in rats. On the other hand, antiproliferative properties on cancer cells evaluated in SW480 and SW620 cells lines showed that cell growth in both lines was inhibited with $50\text{--}500 \mu\text{g mL}^{-1}$ of leaf ethanolic extracts and maracuyá fruit juice [163]. The polysaccharide peel of maracuyá fruits was also evaluated for its antiinflammatory effects and antidiabetic properties. In this context, the reduction of the inflammation was associated with the liberation or synthesis of histamine and serotonin, in response to a polysaccharide fraction of the maracuyá fruit [164]. Moreover, flour peel of maracuyá fruits in diabetic rats showed a decline in glucose content in the blood [165], probably associated with the high fiber level in this fruit tissue, which could prevent absorption of carbohydrates [166, 167]. Furthermore, triglycerides levels significantly decreased with 25 mg kg^{-1} of flour peel, however, no changes in total cholesterol levels were observed [165]. Still, Barbalho et al. [167] concluded that maracuyá fruit juice could improve the lipid profile, including the triglycerides, cholesterol, LDL-cholesterol, and HDL-cholesterol levels.



Figure 8. Fruits of *Passiflora edulis* commonly name maracuyá.

4. Conclusion and perspectives

A wealth of information in the field of phytochemical compounds and their impact on human health has been generated. Nowadays, it is possible to affirm that fruits and vegetables must be a part of daily diet. This is not simply a recommendation, but must be treated as an urgent

requirement to ameliorate human health, especially in decreasing chronic nontransmissible diseases. We believe that additional efforts of governments and diverse organisms related with human health are necessary in order to highlight the benefits of these food types. Coriander and kiwifruit have remarkable characteristics and are excellent functional foods. We highlight these species for their wide range of benefits in different human diseases and their worldwide distribution. Likewise, further investigation is required to understand the mechanisms associated with several biochemical and physiological processes induced by fruit and vegetable intake in humans. Furthermore, we consider that leeks and artichokes have special potential as functional foods. Although there is a lot of information about the beneficial effects of fruits, we believe it is possible to extend studies to other organs like leaves and stems in artichokes, and roots in leeks, because they can offer additional benefits to human health.

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