CHAPTER

34

Bioactive Compounds in Mango (*Mangifera indica* L.)

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1. INTRODUCTION

1.1 Importance of Mango in the Global Market

Mango (*Mangifera indica* L.) is a member of the *Anarcadiaceae* family which comprises more than 70 genera. Historical records suggest that its cultivation as a fruit tree originated in India around 4000 years ago. In the early period of domestication, mango trees probably yielded small fruits, but folk selection of superior seedlings over many hundreds of years would have resulted in the production of larger fruits [1].

Before 1970, mangoes were little known to consumers outside the tropics and the trade involving fresh fruit was non-existent. There was, nevertheless, in the subsequent years, a rapid expansion of mango production into non-traditional areas and the mango trade became well established as fresh fruit and processed products [2].

With a growing world production, the mango represents one of the most important tropical fruits and is produced worldwide. Mango production is, however, quite concentrated, since Asia accounts for approximately 77% of global mango production, and America and Africa account for the remaining 23% [3].

The mango is an important fruit for human nutrition in several parts of the world. It is a tropical fruit widely accepted by consumers throughout the world for its succulence, sweet taste and exotic flavor, being called the 'king of fruits' [4]. Mango flesh is consumed in varied forms in both ripe and unripe stages. It is mostly eaten fresh, but a vast range of processed foods and drinks can be prepared, such as pickles, beverages, vinegar, chutneys, and desserts, as well as dessert flavoring and meat tenderizer.

Along with the trade expansion of fresh mangoes, there has been an increase in world demand for processed mango products [5]. Fruit processing is one way to reduce losses at peak harvest periods and to maximize the fruit's great potential through varied products, including juices, nectar, flesh, and others. Besides, since the mango is a fruit with high

nutritive value, it is quite advantageous from the human health standpoint to enable fruit supply throughout the year via processed products. Mango processing also allows the use of less appealing varieties which cannot be sold on the fresh fruit market. Not only can the mango flesh be used for human food, but the waste originating from mango processing is a source of both macro- and micronutrients.

This chapter reviews data from studies on nutrient and non-nutrient phytochemicals in mangoes, focusing on their contents, biological action, and antioxidant activity.

1.2 Mango as a Fruit with High Functional Potential

The concept of a healthy diet has changed over the years. It was believed that a healthy diet provided all nutrients at adequate levels. Currently, besides supplying nutrients at adequate quantities and quality, it is believed that a healthy diet should have additional attributes, contributing to protection against diseases. Such protection is achieved by the presence of bioactive compounds contained in 'functional foods,' which are defined as 'a food that may provide a health benefit beyond the traditional nutrients it contains' [6].

Despite these divergent concepts, there are opinions that a functional food can be a natural food [6]. Within this concept, the mango can be included in the category of functional foods, since it provides the human diet with macro- and micronutrients and contains a large pool of bioactive compounds that are relevant to improving health and reducing the risk of disease. Furthermore, other parts of mango are also rich in bioactive compounds and nutrients, and could be exploited as nutraceuticals or active ingredients in the provision industry.

1.2.1 Macronutrients

Macronutrient composition of mango flesh seems to differ very little among varieties. A study carried out in our laboratory evaluated the composition of four mango varieties showing that it contains low levels of lipids and proteins and approximately 15% of total carbohydrate. Like most fruits, mango flesh contributes little to the caloric supply of a diet (Table 34.1).

Agricultural residues of mango are also a source of nutrients. The macronutrient content of flour obtained from mango kernels (variety Ikanekpo, Nigeria) presented the following composition per kilogram: protein (66.1 g), fat (94.0 g), fiber (28.0 g), and starch (500.0 g) [7]. Although mango seed kernels have low protein contents, the composition of essential amino acids indicates a good quality protein. The pattern in limiting amino acids (methionine, cystine, isoleucine, and valine) seems to differ among cultivars [7,8]. Investigations on the compositional quality of mango seed kernel of Egyptian varieties (Zebda, Balady, and Succary) revealed all essential amino acids to be present at higher levels than those of FAO reference protein [9].

TABLE 34.1 Chemical Composition[a] of Mango Flesh from Four Varieties (g/100 g Fresh Weight)

Variety	Moisture	Protein	Lipid	Total Carbohydrate	Ash	Kcal(Kjoule)
Haden	83.61	0.64	0.15	15.31	0.29	65.15(272.77)
Tommy Atkins	84.38	0.55	0.07	14.67	0.29	61.51(257.53)
Palmer	81.96	0.59	0.09	17.02	0.34	71.25(298.31)
Ubá	83.17	0.50	0.14	15.87	0.32	66.74(279.43)

[a]Ribeiro, S. M. R. (2006). Mango (*Mangifera indica* L.) antioxidant potential: characterization and evaluation. Thesis (Doctor Science). Department of Molecular Biology and Biochemistry. Federal University of Viçosa, Brazil.

However, it needs to be noted that the presence of tannins [10] can reduce the biological value of the protein.

Mango kernel has fat contents ranging from 6 to 12% on a dry matter basis, and the profile of fatty acids shows high levels of stearic and oleic acids [9,11] with physical properties adequate for use by the food industry. Mango seed fat has been approved by European Union authorities as a cocoa butter substitute.

There are few studies on the content and quality of dietary fiber in mango flesh. It is likely that there are significant differences in the amounts and quality of fibers among mango varieties, since some varieties contain much higher amounts of fiber than others. This is one of the main characteristics influencing consumer preference for fresh consumption varieties, as low-fiber or fiberless flesh is mostly preferred. Keitt mango growing in Florida, in unripe and ripe states, had total dietary fiber contents of 1.6 and 1.4 g/100 g fruit, respectively, and a large proportion consisted of pectin [12]. Some studies have focused on the analysis of mango peel, because this can be considered a source of dietary fiber of excellent quality. Peels of Haden variety contain high amounts of soluble (281 g/kg of dry matter) and insoluble fiber (434 g/kg) [13], and a large fraction of the soluble fiber is pectin [14,15].

1.2.2 *Micronutrients*

Various studies have demonstrated that the mineral content in mango flesh is not high [16,17] and, therefore, mango flesh is not considered a good dietary source of these nutrients. In contrast, fiber from mango peel (variety Haden) had high contents of some minerals that are important for human nutrition, including calcium (4445 mg/kg), potassium (2910 mg/kg), magnesium (950 mg/kg), iron (175 mg/kg), and zinc (32.5 mg/kg) [13].

Mango flesh contains provitamin A carotenoids, with β-carotene being the most abundant carotenoid in many varieties [18,19]. This attributes an additional nutritive value to the fruit because β-carotene is the carotenoid that possesses the highest provitamin A activity. Therefore, mango consumption is very important for some populations in tropical regions, where the deficiency of vitamin A constitutes a public health problem [20]. A study using an *in vitro* model indicated that there are varietal differences in the content and bioavailability of β-carotene from mango, and the ingestion of flesh blended with milk is beneficial, increasing the bioavailability [21]. However, *in vivo* studies would be more appropriate to clarify this question.

Mango flesh contains ascorbic and dehydroascorbic acids [22,23], and the fruit can be considered an excellent source of vitamin C for the human diet, for two reasons: first, the flesh, the most commonly consumed form, provides favorable conditions for preservation of ascorbic acid when compared with other fruits that are predominantly consumed as juices or with cooked vegetables; second, organic acids, mainly citric and malic acids, can stabilize ascorbic acid through metal chelation [24]. In addition, phenolic compounds also present in mango flesh provide protection against ascorbate oxidation [25].

Therefore, the daily consumption of mango fruits by population groups of all life stages should be increased to meet the recommended dietary requirements of vitamins A and C.

2. BIOACTIVE COMPOUNDS IN MANGO

Apart from being important as a food, mango fruits as well as other parts of the plant are a source of bioactive compounds with potential health-promoting activity (Table 34.2).

All parts of mango trees have been used in traditional South Asian medicine: kernels, flowers, leaves, gum, bark, and peel. Diseases commonly treated with herbal remedies obtained

TABLE 34.2 Bioactive Compounds in Mango

Bioactive Compound	Part
Ascorbic and dehydroascorbic acids	Flesh
β-carotene	Flesh
Other carotenoids: ζ-carotene, mutatochrome, α-cryptoxanthin, violaxanthin, luteoxanthin, mutatoxanthin, auroxanthin	Flesh
Polyphenols: mangiferin, isomangiferin, homomangiferin, quercetin, kaempferol, anthocyanins	Flesh, bark, seed, peel, leaves, twigs
Phenolic acids: gallic, protocatechuic, ferulic, caffeic, coumaric, ellagic, 4-caffeoylquinic acids	Flesh, peel, seeds, kernel
Other phenols: Alk(en)ylresorcinols	Peel, sap
Fiber	Peel, seed, flesh
Terpenoids: α-pinene, β-pinene, β-myrcene, limonene, *cis*-ocimene, *trans*-ocimene, terpinene, α-guaiene, camphene, fenchene, α-humulene and others (lactones, aldehydes, acids, sesquiterpenes, esters and aliphatic alcohols)	Flesh, peel, sap
Antioxidant minerals: potassium, copper, zinc, manganese, iron, selenium	Flesh, peel, seed, stem bark

from parts of the mango tree include dysentery, diarrhea, urinary tract inflammation, rheumatism, and diphtheria. A number of these uses are supported by scientific evidence [26]. Vimang®, an extract obtained from the stem bark of mango trees, shows *in vitro* and *in vivo* anti-inflammatory and antioxidant activities and is currently produced on an industrial scale in Cuba [27]. Aqueous decoctions of mango flowers showed potential gastroprotective and ulcer-healing properties in the acute and subacute models of induced ulcer in mice and rats [28]. Extracts of mango leaves showed moderate larvicidal activity in experiments with *Culex quinquefasciatus* Say, the main mosquito vector of lymphatic filariasis, which is widely distributed in tropical regions [29]. The natural product used in Cuban traditional medicine, obtained from mango bark (MSBE), modulated the P450 enzymes in cultured cells, demonstrating inhibition of CYP1A2 and 2E1. The authors postulate that, by this mechanism, chemopreventive properties could be attributed to the natural product, since both P450 enzymes are involved in the bioactivation of mutagens and carcinogens [30]. One study has indicated that peel extracts from mango had thyroid stimulatory effects on animals with induced hypothyroidism, and reduced lipid peroxidation in heart, liver, and kidney tissues [31]. Extracts from mango kernel showed superoxide anion scavenging activity in a cell-free system [32], suggesting one possible bioactivity by antioxidant mechanism. Mangiferin, a xanthone present in mango, when administered at a dose of 100 mg/kg/d to rats subjected to experimental periodontitis, demonstrated an anti-inflammatory property, accelerating the processes of repairing and healing injured tissues [33].

Bioactive compounds present in fruits have attracted attention from both the consumer and the scientific community, considering strong epidemiological evidences that show the benefits of fruit intake in human disease prevention [34,35]. Mangoes contain several constituents which are included in the category of bioactive compounds with a great potential to modulate risk factors of diseases.

2.1 Ascorbic and Dehydroascorbic Acids

The term 'vitamin C' comprises the sum of ascorbic acid (AA) and dehydroascorbic acid (ADA) because ADA can be converted to AA in humans [36]. Similar to other fruits, mangoes differ in their ascorbic acid content because of genotype variations, climatic factors, agricultural practices, and ripening stage [37]. Literature reports indicate great variation in ascorbic acid contents, ranging from 9.79 to 186 mg per 100 g of mango flesh [22,23,38–42]. Besides other factors, such variation can be partially attributed to ripening stage, since ascorbic acid content declines during the maturation

process. Therefore, products made from unripe or half-ripe mangoes usually have higher ascorbic acid content than those produced from ripe fruits. Apart from differences in the raw material, the large variations observed for vitamin C may be attributed also to differences in sample preparation and the analytical methods used for quantification. Another possible reason for the inconsistent reports is the fact that ADA contents were not always considered in previous investigations.

In addition to its function as scurvy preventing agent, ascorbic acid is considered a potent water-soluble antioxidant because the molecule can donate a hydrogen atom and form a relatively stable ascorbyl free radical, with a half-life of approximately 10^{-5} seconds [43]. The antioxidant effect of ascorbate is related to its capacity to remove reactive oxygen species (ROS) by reacting with superoxide radicals, hydrogen peroxide, hydroxyl radicals, and singlet oxygen [44]. It also removes reactive nitrogen species (RNS), preventing nitration reactions [45]. It is believed that ascorbate participates in the regeneration of tocopherol, and this explains the antioxidant synergism between the two nutrients. It is considered an antioxidant protector of cell soluble compartments, and helps to maintain tocopherol in its reduced form, being, therefore, considered a vitamin E 'regenerator.' By participating in reactions as reducing agent, ascorbate is oxidized, forming dehydroascorbate, which can be regenerated by specific reducing systems in the organism [46].

Intake levels of ascorbic acid can modify risk factors of cardiovascular diseases and cancer. A study by Block et al. has pointed out that the plasma level of vitamin C is inversely related to blood pressure in young black and white women [47], reinforcing previous evidence that a low vitamin C status may increase the risk of mortality from cancer and cardiovascular disease [48]. Evidence based on the prospective study indicated that higher plasma vitamin C levels are inversely associated with gastric cancer [49], and studies on the molecular mechanism of biological action suggest the role of vitamin C in the protection of the DNA against mutations [50].

2.2 Carotenoids

Mango flesh contains a wide pattern of carotenoids, including β-carotene, violaxanthin, cryptoxanthin, neoxanthin, luteoxanthin, and zeaxanthin [19,22,23,51–53]. There is also a wide variation in β-carotene (550 ~3210 μg/100 g) and total carotenoid (1159 ~3000 mg/100 g) contents in flesh of different mango varieties [19,21–23,51–57]. However, since many of these studies do not characterize the maturity of the fruit tested, it cannot be concluded whether the differences are attributable to varietal characteristics or related to other factors, including ripening stage. Incidence of sunlight may induce carotenogenesis as a fruit defense mechanism, protecting it against UV radiation injuries [58]. Mango production on a commercial scale uses sophisticated management to ensure fruit quality characteristics and some of these strategies may influence the content of bioactive compounds. For example, a CaO solution is used for fruit protection against injuries from excess sunlight. In theory, this practice can influence the fruit physiological response, decrease carotenogenesis, and thus reduce the carotenoid content in the fruit. There are indications of varietal differences in amounts of each minor carotenoid pattern [21].

Many hundreds of carotenoids are found in nature, but the five main ones found in human tissues are β-carotene, lutein, lycopene, β-cryptoxanthin, and α-carotene [59]. Carotenoids are important not only because of their provitamin A activity but also because of a number of other actions in biological systems. In animal tissues, because of their lipophilicity, carotenoids are distributed in apolar compartments, including membranes, lipoprotein particles (LDL

and HDL), and serum, bound to a transport protein [60].

Carotenoids are efficient as ROS quenchers, specifically singlet oxygen and peroxyl radicals. The antioxidant properties of carotenoids explain their protective effects against diseases related to oxidative stress [61]. However, gene modulation seems to be the most relevant biological mechanism of carotenoid action in some pathological processes. Carotenoids affect gene expression regulation. Nuclear retinoic acid receptors bind to retinoic acid-responsive elements [62], and this event results in the expression of specific genes. Connexins are gene products that have been extensively investigated, since they increase cell-to-cell communication and thus affect cell proliferation. Cancer cells communicate poorly with normal cells and proliferate abnormally [63]. These carotenoid–gene interactions seem to explain part of the associations between high carotenoid intake and lower cancer incidence observed in epidemiological studies. These studies suggest a positive correlation between higher intake and tissue concentrations of carotenoids and lower risk of certain diseases, such as cardiovascular diseases, some types of cancer, osteoporosis, infectious diseases, cataract, and others [64]. One study with older adults has demonstrated that higher total plasma carotenoids were associated with a significantly lower risk of developing severe walking disability [65].

2.3 Phenolic Compounds

The presence of the phenolic compounds glucogallin and gallotanin in mango flesh and seeds, and mangiferin, isomangiferin, homomangiferin, fisetin, quercetin, isoquercitrin, astragalin, gallic acid, methyl gallate, digallic acid, β-glucogallin, and gallotanin in leaves, twigs, seeds, and fruits of 20 local varieties was described already in 1971 [66].

It has been reported that the total content of phenolic compounds in mango flesh ranges from 9.0 to 208.0 mg/100 g [22,42]. Peels and kernels contain large amounts of extractable phenolics, and there are varietal differences in their contents [16]. A wide pattern of phenolic compounds has been described in the flesh, peels, and kernels of mangoes (Table 34.2) [67–72]. In particular, flavonols and xanthones have been identified and quantified (Table 34.2) [70–72]. The flavonols (quercetin, kaempferol, and rhamnetin) are present mostly as *O*-glycosides, whereas mangiferin is a *C*-glycoside and occurs both in its non-esterified form and conjugated with gallic acid.

There are varietal differences in the profile and content of flavonols and xanthones in mangoes originating from several countries [71], whereas the qualitative profile is relatively conservative. It seems that phenolic compounds are the main antioxidant constituents with greater variation in mango, because they are plant secondary metabolites and their contents differ not only by genetic characteristics and maturity stage but also agricultural practices. Studies with mango varieties demonstrating significant differences in the phenolic pattern raised the hypothesis that growing mangoes using simple management practices and pesticide-free technology enables the natural plant and fruit defense against environmental adversities. It results in the increased synthesis of secondary metabolites (phenolic compounds), and therefore improves functional properties of the fruits [70].

Quercetin and kaempferol belong to the flavonoid class and have been receiving great attention as bioactive compounds for many years. A wide range of biological activities, including antibacterial, antithrombotic, vasodilatory, anti-inflammatory, and anticarcinogenic effects mediated by different mechanisms, are associated with flavonoids [73]. Inverse relations were found between the dietary intake of some flavonoids and incidence of several chronic diseases [74,75].

Quercetin (3,3′,4′,5,7-pentahydroxyflavone) is a potent antioxidant [76] because its structure

contains a double bond in the C-ring and the 4-oxo group, which are structural determinants that enhance its action as an antioxidant [77]. Studies have shown biological effects of quercetin on inhibition of protein kinases, DNA topoisomerases, and regulation of gene expression [78]. There is consistent evidence from these studies that quercetin may reduce the risk of cancer. Pretreatment of primary hippocampal cultures with quercetin attenuated β-amyloid induced cytotoxicity, protein oxidation, lipid peroxidation, and apoptosis, suggesting that quercetin may provide a promising approach for treatment of Alzheimer's disease and other oxidative stress-related neurodegenerative diseases [79].

Kaempferol (3,5,7,4′-tetrahydroxyflavone) has a chemical structure with various hydroxyl substitutions, transforming the molecule into a potent antioxidant [80]. Associations among kaempferol intake and reducing risk factors of chronic diseases have already been suggested [74]. A population study showed that higher intakes of kaempferol tended to lower ischemic heart disease mortality, and the incidence of brain vascular disease leading to hospitalization or death was also diminished [74].

Biological actions of mangiferin (1,3,6,7-tetrahydroxyxanthone-2-glucopyranoside) have been exhaustively studied, and several investigations have confirmed the bioactivity of xanthones. Studies conducted with VIMANG®, a formulation manufactured in Cuba that contains mangiferin as the main active ingredient, demonstrated protective effects on hepatic and brain tissues of mice against induced oxidative stress [81]. The inhibitory effect of mangiferin on carcinogenesis in rats [82], and against induced oxidative stress in cardiac and renal tissues of rats was also demonstrated [83]. Mangiferin showed antioxidant activity by eliminating the superoxide radical in *in vitro* tests, in which 100 μM of mangiferin was equivalent to the activity of 1 U/mL of superoxide dismutase, besides having other pharmacological effects modulating gene expression related to the inflammatory response [84].

Studies on the immunomodulatory activity of mangiferin showed that xanthone modulates the expression of various genes critical for apoptosis regulation, viral replication, tumorigenesis, inflammation, and autoimmune diseases. These results suggest its possible value in the treatment of inflammatory diseases and/or cancer [85]. Mangiferin protected human lymphocytes from DNA lesions when exposed to gamma radiation, raising the possibility of its use in patients undergoing radiotherapy or people occupationally exposed to radiation [86].

Evidence now indicates that mangiferin is a promising chemopreventive [87], with bioactivity involving antioxidant action [88] and modulation of gene expression [89,90]. In another study, mangiferin was shown to provide protection against gastric injury induced by ethanol and indomethacin [91]. It must be emphasized that mangiferin is present in peels, bark, and leaves in higher concentrations than in the flesh and that xanthone derivatives have not been detected in some varieties [70]. Hence, the hypothesis has been raised that mangoes growing in more natural conditions may contain higher xanthone levels than others subjected to treatment against physical and microbial injuries. Singh [92] confirmed that the mangiferin content was higher in cultivars resistant to malformation syndrome associated with abnormal inflorescence and suggested that xanthone could be a potent inducer of plant natural defense.

Alk(en)ylresorcinols are phenolic lipids that are present in mango peels and sap. They have been demonstrated to possess antifungal and anti-inflammatory activities [93–95].

2.4 Terpenoids

Terpenoids are compounds belonging to the prenyl lipids class and represent probably the

most widespread group of natural products. Monoterpenes and diterpenes, the main components of essential oils, can act as allelopathic agents, as attractants in plant–plant or plant–pathogen/herbivore interactions, or as repellents. In addition to carotenoids, which are tetraterpenoids, mangoes contain mono-, di- and triterpenoids, including ocimene, myrcene or limonene, terpinolene, and carene [96–99]. Several factors can affect the biosynthesis of aroma volatile compounds in mango [100–105].

There is currently a good prospect for exploiting the biological activity of terpenoids, as previous studies indicated that monoterpenes inhibited cell growth, cell cycle progression, and cyclin D1 gene expression in human cancer cell lines [106]. Monoterpenes would appear to act through multiple mechanisms in cancer chemoprevention and chemotherapy [107]. Mono- and diterpenes are effective antioxidants and studies have demonstrated their *in vitro* antioxidant activity [108,109]. Another study showed that combinations of rutin with terpinene can have synergistic effects by acting as hydrophilic and lipophilic antioxidants [110]. Studies have demonstrated terpenoids to act as chemopreventive agents [111]. Lupeol, a triterpene present in mango, has shown apoptogenic activity in mouse prostate by early increase of reactive oxygen species [112,113]. The anti-urolithic effect of lupeol and lupeol linoleate has been demonstrated in experimental hyperoxaluria [114]. These evidences indicated that terpenoids in mangoes have biological activity, contributing to raise the functional potential of the fruit, and the need for further studies to investigate their nutraceutical effects.

2.5 Fiber

Studies on mango flesh showed that a high proportion of the fiber fraction consists of pectin and its content in the peel is also quite high ([14,15]. Pectin is not hydrolyzed in humans by endogenous digestive enzymes but is fermented by the colon microflora [115], thus showing a prebiotic effect. Its biological activities have attracted interest in the last decades, because of their postulated positive effects on health such as cholesterol-lowering [116], cancer-preventing [117], and blood glucose-regulating properties [118,119]. Studies have since demonstrated that soluble fiber can stimulate protein turnover in intestines and liver [120].

The presence of pectin in mango flesh adds to it a functional attribute, and this points to the need for further investigation of fiber in mango flesh from different varieties. Fiber extracted from fruit agro-industrial residues can be used in the industry as a food ingredient [14,121,122]. Although the pectin extracted from mango peel had net yield similar to apple pectin, its low content of anhydro-galacturonic acid leads to a low jellifying capacity [15].

2.6 Antioxidant Minerals

In the area of human nutrition, selenium, copper, zinc, iron, and manganese are included in the group of antioxidant minerals and their deficiency in the body affects the activity of enzymes involved in protection against oxidative stress. Thus, copper, zinc, manganese, iron, and selenium have been considered essential minerals for the optimization of the antioxidant enzyme response.

Compared with other foods, mango flesh contains lower levels of antioxidant minerals such as copper, iron, manganese, and zinc [16,17]. Nevertheless, the mineral content should not be neglected because mango consumption is associated with the intake of numerous antioxidants acting synergistically. Stem bark of mango trees grown in Cuba presented high concentrations of copper, iron, selenium, and zinc. The authors suggested that

these elements contribute to the antioxidant activity of this product [123].

3. TOTAL ANTIOXIDANT CAPACITY OF MANGOES

Bioactive compounds can protect against diseases via several mechanisms, but it is believed that the antioxidant activity is extremely important for protection against diseases related to oxidative stress [124]. Mango contains at least three classes of compounds, i.e. ascorbic acid, carotenoids, and phenolic components, that can support the antioxidant defense in humans. Despite the low content of the minerals copper, zinc, manganese, and iron in mango flesh, their importance should not be disregarded, as the fruit intake provides a set of antioxidants that may offer protection to the organism in a synergistic way.

The *in vivo* action of antioxidants demonstrates the synergism phenomenon, which is a cooperative action among several substances with antioxidant properties to protect oxidation targets [46,125]. Synergism occurs by co-antioxidant effect, involves more than one antioxidant with different reduction potentials and polarities participating in redox reactions in a system under pro-oxidant conditions, until a nonreactive product is formed, stabilizing the medium. Considering that mango contains this group of compounds, it can be assumed that the mango is a fruit with high antioxidant potential. Evidence suggests that a single antioxidant cannot replace a combination of antioxidants. Thus, a powerful antioxidant defense can be achieved in the biological media through mango consumption.

Total antioxidant capacity of foods has been suggested as a tool for investigating the health effects of antioxidants in mixed diets [126], and there is evidence that food selection based on total antioxidant capacity can modify antioxidant intake, system inflammation, and liver function without altering markers of oxidative stress [127].

A comparative study carried out in our laboratory to investigate the antioxidant potential of four mango varieties indicated that the flesh extracts showed capacity to scavenge diphenylpicrylhydrazyl (DPPH) radicals in a dose-dependent manner with scores similar to or above the antioxidant standards gallic acid, butylated hydroxyanisole (BHA), and catechin at 100 ppm (Figure 34.1 A and B). There were significant differences in the antioxidant activity of the mango flesh extracts among varieties, for both reducing power and radical scavenging activity (RSA) tests (Figure 34.1 A and B). In all tested concentrations, the extract of mango variety Ubá showed scavenging activity significantly higher than the others, because the antioxidant contents in fruits of variety Ubá were higher [22], contributing to the positive effect in both antioxidant tests.

Other studies have demonstrated the total antioxidant capacity of mangoes [12,14,23,128]. During mango processing, the peels emerge as a byproduct and are usually discarded as waste. A number of valuable antioxidant compounds are contained in this residue [129]. For this reason, there are studies addressing the use of natural antioxidants obtained from mango agro-industry residues as food preservers in substitution to artificial antioxidants [130,131].

Furthering the research carried out in our laboratory, an *in vivo* study was performed to measure the antioxidant potential of Ubá mangoes because this variety presented high antioxidant activity in previous *in vitro* tests. Biological assays were carried out with Wistar rats in an induced oxidative stress model. The animals received acetaminophen, in a dose sufficiently high to induce oxidative stress in the liver as demonstrated in another study [132]. We performed an experiment supplementing the animals' diet with lyophilized mango flesh at 3%, which is a concentration equivalent to

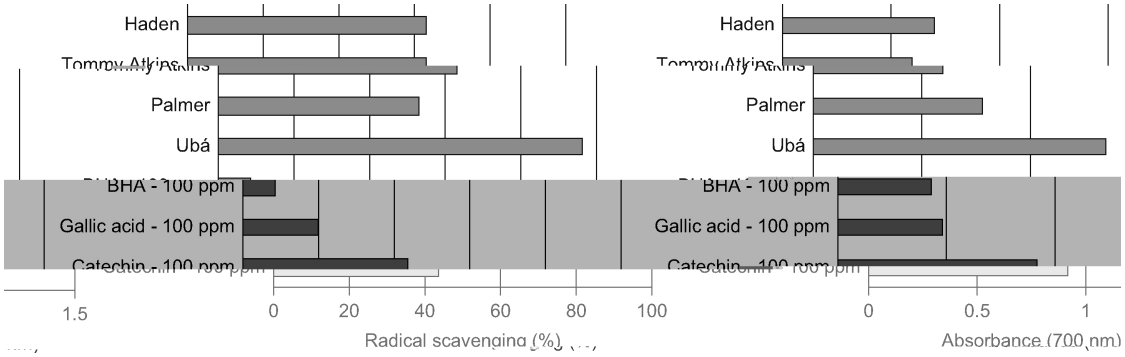

FIGURE 34.1 Antioxidant activity of mango flesh extracts from four varieties and antioxidant standards, measured by radical scavenging[1] (A) and reducing power[2]z (B) tests.

[1]Determined according to Blois, M. S. (1958). Antioxidant determinations by use of a stable free radical. *Nature* **181**, 3–14.
[2]According to Oyaizu, M. (1986). Studies on products of the browning reaction. Antioxidative activities of browning reaction products prepared from glucosamine. *Eiyogaku Zasshi* **44**, 307–315.

human consumption level. After having induced the oxidative stress, the animals were fed the diet containing mango at 3% in the subsequent 24 hours. The animals were then euthanized, and blood and liver were collected for analysis. A hepatoprotective effect was demonstrated with reduction of serum aminotransferases, mediated by antioxidant mechanism with decreased lipid peroxidation in liver homogenates. This finding confirmed that at concentrations similar to usual human consumption, mangoes provided protection to hepatic tissues against induced oxidative injury. These studies have demonstrated the potential bioactivity of compounds in mango flesh involving redox mechanisms.

4. SUMMARY

Mango is a fruit with high nutritional value, supplying the human diet with calories, fiber, vitamins, and minerals. Flesh and agro-industrial residues (peels and seeds) of mangoes contain several bioactive compounds, comprising nutrient and non-nutrient substances with biological properties that act mainly via redox mechanisms. Compounds contained in mango flesh can act as biological antioxidants maximizing the human antioxidant defense. Additive and synergistic effects of bioactive compounds from mangoes suggest that the fruit has great potential to improve health and reduce the risk of chronic diseases.

Despite the numerous bioactive compounds in mangoes, which may promote benefits to human health, the potential for allergenicity of the fruit has been shown. Conventional technological processing of mango into flesh-containing products does not allow complete elimination of the allergenic potency [133].

All mango varieties can supply the diet with nutrients, but considering that the contents of bioactive compounds are influenced by several factors, it was assumed that population groups with the same mango intake may be ingesting such compounds at different levels, not guaranteeing a comparable modulation potential of risk factors of diseases. Figure 34.2 summarizes some potential mango benefits for

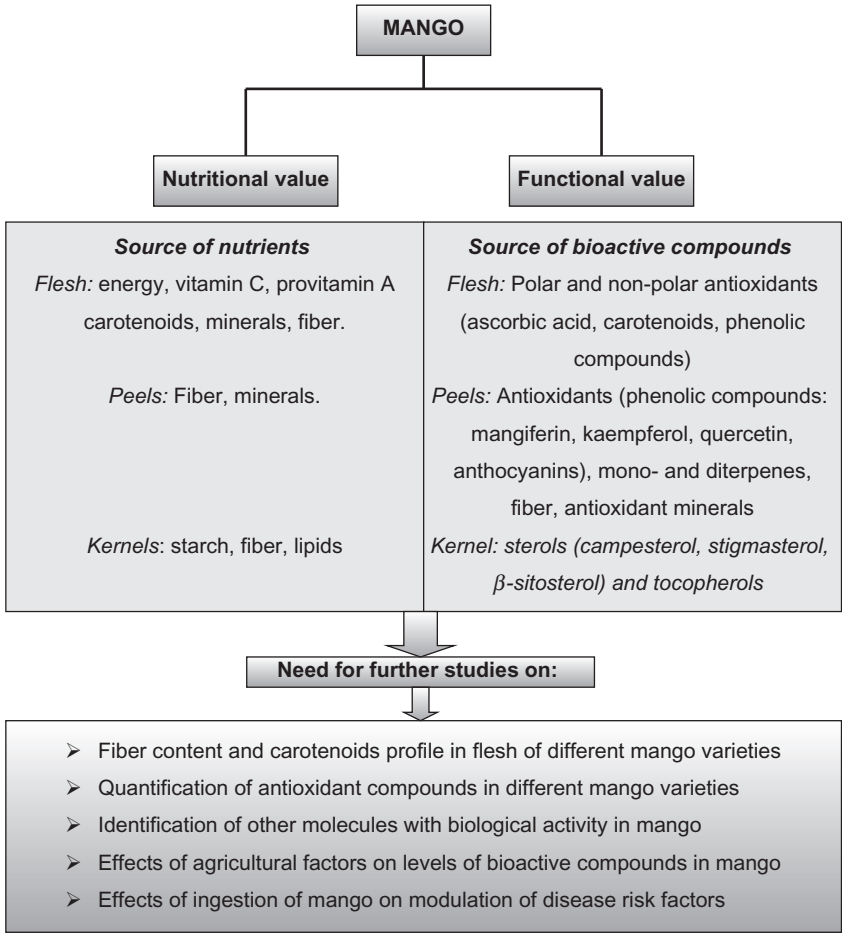

FIGURE 34.2 Nutrients and non-nutrient compounds in mangoes with health-promoting activity, and perspectives for future studies.

human health to be exploited, considering current knowledge.

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