Nutritional Quality of *Mangifera* Species

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Abstract

Mango is known as the king of the fruits; its nutritional importance, unique flavor, and delicious taste impart this status as super fruit. Furthermore, it is commercially cultivated in different tropical and subtropical areas in the world. *Mangifera indica* is the most important fruit of this genus; over 60 different species of edible mangoes are grown worldwide; however, the most of them are not marketable

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and underutilized and commonly are denominated as wild mango species, but they exhibit higher nutritional values. Mango species present morphological, physiological, sensorial, and nutritional differences among them. However, most of *Mangifera* species are characterized by their strong aroma, intense peel coloration, attractive fragrance, and delicious taste. Also, mango fruit is considered very healthy, good source of energy, and easily digestible.

Mango pulp and peel are a good source of carbohydrates, dietary fiber, vitamins (B, C, and E), minerals (Ca, P, Fe, Na, and K), and bioactive compounds (polyphenolic compounds, flavonoids, mangiferin, lupeol, and carotenoids). Most of *Mangifera* species have good nutrimental quality; their consumption may contribute nutrition. In general, the commercially (*M. indica*) and wild mango species can be considered for many purposes including for processing and for consumption because mango may be considered an excellent source for improving nutrition. However, enhanced knowledge of the status of such species and information on their health benefits is critical in efforts to promote these valuables mango species.

Keywords

Mangifera species · Wild mango · Nutritional quality · Bioactive compounds · Health benefits

Abbreviations

AA	Ascorbic acid
DF	Dietary fiber
DRI	Dietary reference intake
DW	Dry weight
IDF	Insoluble dietary fiber
SDF	Soluble dietary fiber
TA	Titratable acidity
TDF	Total dietary fiber
TSP	Total soluble polyphenols
TSS	Total soluble solids

1 Introduction

Mango fruit has been recognized as the "king of the fruits," having socioeconomic importance in many countries and/or localities. Mango fruit is cultivated commercially in more than 87 countries around of the world, but also, mango ranks among major fruits worldwide [1, 2]. Furthermore, mango is a rich source of bioactive compounds and essential macro- and micronutrients; it is a powerful nutritive fruit, containing most of the essential substances needed by the human health. Its nutritional importance, unique flavor, and delicious taste impart this status as super fruit [3].

Mangifera is a genus that belongs to the Anacardiaceae family in the order of Sapindales, which is native to the Southeast Asia, in particular originated in India, Indo-Myanmar border, and Bangladesh [4]. Kostermans and Bompard [5] listed 58

species in the genus *Mangifera*, but today, this number is considerably increased [4]; majority of which were distributed in Asia. Currently, mango is cultivated in different tropical and subtropical areas worldwide [6, 7], and it has several species, varieties, and cultivars [8]. Around the world there are more than 150 mango varieties, and the main producers are India, China, Thailand, Indonesia, and Mexico [9]. Previous data are about the best-known species, *Mangifera indica*, a commercially important member of this genus, where the most representative varieties worldwide are "Tommy-Kent," "Tommy Atkins," "Haden," "Keitt," and "Ataulfo" varieties [10]. However, there are another consumable, but not marketable wild mango species in the genus *Mangifera* such as *M. casturi*, *M. zeylanica*, *M. odorata*, *M. lalijiwa*, *M. caesia*, *M. foetida*, *M. laurina*, and *M. pajang*, among others [11]; they represent a great potential for food, industrial, and pharmaceutical use. Unfortunately, the wild mangoes are vulnerable and in danger of extension [12–16].

2 Description of *M. species* Fruits

Mango is a tropical and exotic fruit with many species, varieties, and cultivars [1]. According to Hidayat et al. [6], the classification of *Mangifera* species is still labile; it is because of the complexity of the *Mangifera* genus. Furthermore, several mango fruit characterizations including pulp color (light, yellow, gold, and orange), pulp texture (soft, intermediate, or strong), fiber quantity in pulp, juiciness of pulp (slightly juicy, juicy, or very juicy), pulp aroma (absent, mild, intermediate, or strong), and eating quality (poor, good, very good, or excellent) have been developed [17]. For this reason, mangoes are grouped under two broad categories as wild and cultivated [18]. The fruit description of some edible *Mangifera* species is presented below.

Mangifera indica fruit is more or less compressed, oblong or sub-uniform, fibrous, highly variable in size, shape, weight, and peel coloration and has fleshy drupe with sweet juice and large and compressed seed. In the same way, fruits of *M. andamanica* are oval shaped and small in size and weight (11–15 g); their flesh is yellow, fibrous, and juicy with sweet taste (22 °Brix) [19]. Likewise, *M. caesia* fruit is an ovoid-oblong drupe, necked at base, and medium sized (12–20 cm), with whitish, yellowish, greenish, or pale brownish, smooth, thin skin (1 mm); the pulp is white, soft, juicy, and fibrous, with a peculiar sourish taste; it can be sweet, acidic, or both and has strong smell at maturity [20, 21]. Additionally, the fruits from *M. odorata* are obliquely ellipsoid-oblong or oblong drupe, are medium sized (10–13 cm), and have an average weight of about 200–320 g with a thin skin (3–4 mm) but also are characterized by their strong odor; the pulp is yellow to orange yellow, firm, fibrous, and juicy and has sweet to acidic, sweet taste (21 °Brix). The fruit peel has greenish purple color to canary yellow at maturity [19, 20, 22, 23].

With respect to *M. sylvatica*, the fruit is obliquely ovate, small (8–10 cm long; 27 g), and compressed; the pulp is yellow in color, has a sweet and sour taste, is very aromatic, and is almost fiberless. Their skin is very thin but has a big kernel (40% of its weight). The fruits look very much like that of the common mango (*M. indica*) [24–26]. *M. foetida* fruit is obliquely ovoid-oblong or almost globose drupe, small to

medium in size, dirty dark olive green or yellowish green in color with brown lenticels, fibrous, juicy, savory, and with strong smell and has skin of 5 mm thick and pale yellowish-white flesh when immature that turns into yellow or golden yellow when ripe [20, 21]. *M. laurina* fruit is a drupe-like small mango, obliquely oblong, small in size (5–7 cm), and medium green turning greenish yellow to yellow in color at maturity; flesh is yellow, watery, sweet, with a strong resinous taste, juicy, very acidic, and fibrous [20, 22, 23]. On the other hand, *M. pajang* fruit is a big drupe (2–3 kg), brownish, globose to broad-ovoid, 15–20 cm across, and roughish. Flesh is yellow, fibrous, acidic to acid-sweet, and middy fragrant [20, 21].

Furthermore, the fruits of *M. zeylanica* have an average weight of 150 g; they have a thin skin and are watery, sweet, and pleasant in flavor [22]. Also, the fruit of *M. casturi* is produced in large racemes of ten or more; fruits are small (50–84 g) compared to other mango species; immature fruits are green, and when ripe the color changes to brown or purple black, and it has a shiny surface. The flesh is orange with fiber; its taste is unique (slightly sweet) similar to lychee fruit [21, 22]. The fruits from *M. lalijiwa* exhibited a medium size of fruits (250 g) with green skin; the flesh is white pale yellow with particular brown honey pockets in the flesh. Fruits are very sweet and aromatic with a distinguish honey flavor [21].

In the last years, some research has demonstrated the relationship of some wild mango species, for example, *M. odorata* and *M. foetida* also have close relationship based on internal transcribed spacer nuclear ribosomal DNA [4]. Some authors have mentioned that *M. odorata* is a hybrid result from *M. indica* and *M. foetida* [27]. Also, a close relationship between *M. laurina* and *M. sylvatica* to *M. indica* was previously reported [8].

Mango species exhibited morphological, physiological, and sensorial differences among them. In general, the mango fruit is a simple, large, more or less compressed, fleshy, and resinous drupe. It varies in size, shape, color, taste, and nutritional value. However, most of the *Mangifera* species are characterized by their strong aroma, intense peel coloration, attractive fragrance, and delicious taste.

3 Traditional Uses and Health Importance

Mango fruits can be eaten immature green, mature green, or ripe [20] and usually are consumed fresh with or without peel; however, due to the excellent organoleptic attributes that it exhibits, the pulp is used as an ingredient to elaborate food and beverage products such as juices, nectars, puree, jam, jelly, yogurt, wine, and others [2]. On the other hand, in traditional folk medicine, mango pulp is consumed as an antiparasitic, laxative, and stomachic, among others [1, 28]. According to the World Health Organization, traditional medicine system based on the use of plants is an important source of health care [29]. In recent years, secondary metabolites with known pharmaceutical activities have been extensively investigated as a source of medical agents [30, 31]. In particular, *Mangifera* species exhibited several biological compounds as mangiferin, mangiferic acid, mangiferol, ellagic acid, steroids, alkaloids, terpenoids, saponins, tannins, and others [31, 32]. In this context, the intake of

Table 1 Physicochemical parameters of different flesh *Mangifera* species at green mature stage (GSM) and consumed mature stage (CMS)

Parameter	Maturity stage	pH	AT (% citric acid)	TSS (°Brix)
M. indica cv. Tommy-Kent	GSM	3.48	4.26	10.7
	CMS	4.07	2.39	15.1
M. indica cv. Tommy Atkins	GSM	3.62	4.12	10.9
	CMS	3.91	2.08	16.7
M. zeylanica	GSM	3.53	2.19	11.5
	CMS	4.06	1.26	17.7
M. casturi	GSM	3.11	5.02	7.2
	CMS	4.12	2.40	20.4
M. lalijiwa	GSM	3.23	5.49	9.4
	CMS	4.37	1.67	17.2
M. odorata	GSM	3.90	2.83	6.7
	CMS	4.12	2.49	10.6

Source: Barbosa-Gámez et al. [3]

mango pulp promotes strengthening of the body's defenses, mainly due to the presence of bioactive compounds in fruit pulp and peel as discussed below.

4 Postharvest Quality Parameters of *Mangifera* Species

It has been demonstrated that the majority changes related to the quality in mango fruit occur during its ripening [33, 34]. Barbosa-Gámez et al. [3] evaluated the changes in physiochemical parameters (pH, titratable acidity, and total soluble solids) of the pulp of *M. casturi*, *M. lalijiwa*, *M. odorata*, *M. zeylanica*, and *M. indica* cv. Tommy-Kent and Tommy Atkins, which are harvested in two maturity stages (green mature stage and consumed mature stage). In general, changes in pH, titratable acidity (TA), and total soluble solids (TSS) were observed in both maturity stages as shown in Table 1. In all *M. species* studied, an increase in pH and TSS content was reported when green to consumed mature stage, while TA decreases. Furthermore, numerous physical and physiological changes of mango ripening involving surface color, shape, size, shoulder growth, specific gravity, and firmness have been correlated with the fruit maturity stage [1].

5 Nutrimental Quality in *Mangifera* Species

Fruits play an important role in human nutrition by providing additional sources of energy and bioactive compounds, and their consumption is recommended by many health organizations [35]. Mango is a popular and economically important fruit worldwide mainly for its excellent organoleptic properties and nutritional value [32]. According to Masibo and He [36], mango fruit is unique because each of its parts

(pulp, peel, and kernel) is utilizable. In the literature, mango is described as a fruit with high amounts of water (72–86%) and carbohydrate (9–25%) and low protein (0.9–5.1%) and lipid (0.2–2.7%) content as presented in Table 2; these values are depending on each *Mangifera* species and can vary with the location of cultivation, variety, and stage of maturity.

In particular, differences in nutrimental contents were observed between *Mangifera* species. *M. zeylanica* exhibited the highest water (86%) and lipid content (2.7%). On the other hand, *M. foetida* exhibited the lowest water (72%) content but the highest carbohydrate (25%) content. With respect to the protein content, *M. lalijiwa* (4.7%), *M. odorata* (4.7%), and *M. casturi* (5.1%) showed similar values. Furthermore, some *Mangifera* species as *M. lalijiwa*, *M. odorata*, *M. casturi*, *M. zeylanica*, and *M. sylvatica* exhibited better nutrimental values compared to *M. indica* cv. "Tommy-Kent" and "Tommy Atkins." The nutrimental quality of the fruit is influenced by species, variety, nutritional status, and environmental conditions during growth of the parent plant [1].

The mango pulp is considered very healthy, good source of energy (63–92 kcal), and easily digestible (Table 2). Furthermore, mango fruit has been considered as a functional food because it is a source of dietary fiber [37]. The importance of dietary fiber (DF) content in fruit and its implications in human nutrition and health as prebiotic and regulating the glucose and lipid levels (cholesterol and triacylglycerols) in blood have been reported previously [38]. The total (TDF), soluble (SDF), and insoluble (IDF) dietary fiber values in some *Mangifera* species pulp at two maturity stages are shown in Table 3. In general, Barbosa-Gámez et al. [3] reported a decrease in total dietary fiber content when unripe to ripe mango fruit in all *Mangifera* species is evaluated. However, all mango species exhibited high amounts of dietary fiber, but *M. lalijiwa* showed the highest content in immature stage (41 g/100 g DW) and *M. zeylanica* in mature stage (20 g/100 g DW).

Vitamins and mineral contribute a major part of nutrimental content of fruits; these compounds are essential nutrients that are required for various biochemical and physiological processes in the body. In the case of mango, significant values of vitamin C, vitamin E, B vitamins (Table 4), calcium, phosphorous, iron, sodium, and potassium (Table 5) were found. Ascorbic acid (AA) or vitamin C is the most important water-soluble antioxidant, usually present and highly bioavailable in tropical fruits [39]. According to the Institute of Medicine's Food and Nutrition Board [40], the dietary reference intake (DRI) for vitamin C is 90 mg/day for males and 75 mg/day for females. In the case of mango, vitamin C content was dependent of each species and varies from 47 to 400 mg per 100 g of edible portion; the highest vitamin C content was found in wild mango species (*M. zeylanica*, *M. pentandra*, and *M. pajang*). Daily consumption of 100 g/day of mango (e.g., *M. indica* by popular) pulp could ensure an intake of 100% of the DRI. Furthermore, an interesting values of vitamin E (3.4–7.8 mg/100 g) and B vitamins as niacin (0.6–329 mg/100 g), niacinamide (8–149 mg/100 g), pyridoxine (4.7–86.2 mg/100 g), riboflavin (0.04–97.6 mg/100 g), and thiamine (0.05–8 mg/100 g) were found in different *Mangifera* species, which are another important vitamin groups for health care [41].

Table 2 Nutrimental composition and energy value (per 100 g of edible portion on fresh weight basis) of different *Mangifera* species

Mango species	Energy (kcal)	Moisture (g)	Ash (g)	Total protein (g)	Total fat (g)	Carbohydrates (g)	Total fiber (g)	References
M. indica cv. Tommy-Kent	66.3	83.5	3.4	4.04	1.5	9.2	–	[3]
M. indica cv. Tommy Atkins	75	85	2.3	3.7	1.8	11.0	–	[3]
M. caesia	47.8–64	81.2–86.5	0.6	1.0	0.2	14.6–11.9	2.4	[20]
M. foetida	76	72.5–78.5	0.8	0.8–1.4	0.2	17.9–25.4	1.8	[20]
M. odorata	69.3–83	79–80	0.7	0.9–1.0	0.1–1.8	15.6–19	1.4	[20]
M. casturi	89.9	85.1	5.3	5.1	1.5	14	–	[3]
M. lalijiwa	89.2	81.2	2.3	4.7	1.6	11.1	–	[3]
M. odorata	63.9	80.1	2.7	4.7	2.3	6.1	–	[3]
M. zeylanica	92.3	86.3	3.6	4.2	2.7	12.8	–	[3]
M. sylvatica	59	85	1.93	5	3.2	1.95	2	[26]

Table 3 Soluble dietary fiber (SDF), insoluble dietary fiber (IDF), and total dietary fiber (TDF) contents (% dry weight) in pulp of different *Mangifera* species

Mango species	Maturity stage	SDF	IDF	TDF
M. indica cv. Tommy-Kent	GSM	5.6	8.9	14.5
	CMS	5.3	8.1	13.3
M. indica cv. Tommy Atkins	GSM	4.7	11.5	16.2
	CMS	4.2	5.2	9.4
M. zeylanica	GSM	12.5	18.0	30.5
	CMS	11.0	8.6	19.6
M. casturi	GSM	10.3	15.0	25.3
	CMS	6.1	12.5	18.6
M. lalijiwa	GSM	6.9	11	17.9
	CMS	5.1	8.3	13.4
M. odorata	GSM	11.8	29	40.8
	CMS	7.3	8.3	15.6

Source: Barbosa-Gámez et al. [3]

Mango is a major source of carbohydrates, dietary fiber, vitamins, and minerals with high energy value but low in calorie. Fresh as well as processed form of mango fruit is an important part of people's diet. Furthermore, most of *Mangifera* species have good nutrimental quality; their consumption may contribute nutrition in many countries around the world. Also, some of these wild mango species have been domesticated for its use and commercialization.

6 Phytochemicals Present in *Mangifera* Species

In addition to their delicious taste, refreshing flavor, aroma, and nutritional value, mango fruit provides "bioactive compounds" to improve human health [34]. Bioactive compounds are defined as "inherent non-nutrient constituents of food plants with anticipated health promoting/beneficial and/or toxic effects when ingested" [42]. According to Raman et al. [7], the concentration of these compounds depends on many factors (e.g., varieties, maturity stage). In general, mango fruit has bioactive compounds in roots, leaves, bark, seeds, peel, and pulp. The types of compounds include β-carotene, isoflavones, vitamin C, mangiferin, gallic acid, lupeol, kaempferol, quercetin, and α-tocopherol, among others [43–45]. All these compounds have great potential for use in food and pharmaceutical industry (Raman et al. [7]). As mentioned above mango fruit is consumed with or without peel; for this reason we will focus on the bioactive compounds present in edible part (pulp and peel) of mango fruit.

6.1 Phytochemicals Present in Mango Pulp

Mango, like most fruits, is an important source of natural compounds considered as bioactives [34]. In the edible part of mango fruit, compounds as polyphenols,

Table 4 Vitamin content in different *Mangifera* species pulp (mg/100 g DW)

Mango specie	Ascorbic acid[a]	Vitamin E[a]	Niacin[a]	Niacinamide[a]	Pyridoxine[a]	Riboflavin[a]	Thiamine[a]	References
M. indica cv. Tommy-Kent	140	5.19	104.2	28.2	15.1	28.2	5.1	[3, 28]
M. indica cv. Tommy Atkins	64.5	7.8	81.1	46.5	14.6	21.1	4.8	[3]
M. caesia	125	7.4	1.2			0.16	0.05	[20, 46]
M. foetida	122		0.6			0.04	0.09	[20, 45, 46, 48]
M. laurina	135							[46]
M. odorata	47		329.2	149	86.2	97.6	7.2	[3, 46, 48]
M. pajang	403							[48]
M. casturi	100	4.8	87	66	46	25	8	[3]
M. lalijiwa	97.6	3.8	50	8	4.7	7.2	3.1	[3]
M. pentandra	400							[46]
M. longipetiolata	322							[46]
M. zeylanica	400		160	36	30	30	6.8	[3, 46]

[a]Results are expressed as mg per 100 g DW

Table 5 Mineral content in different *Mangifera* species pulp (mg per 100 g DW)

	Minerals				
Mango specie	Ca	P	Fe	Na	K
M. indica	10		0.13		
M. caesia	7	17	0.3	1	120
M. foetida	16	19	0.2	2	361
M. odorata	9	13	0.4	2	187

Source: Lim [20]

phytosterols, isoflavones, and β-carotene, among others, have been identified as shown in Table 6.

Polyphenols are among the most extensive groups of phytochemicals present in fruits. Mango is an excellent source of dietary antioxidants as phenolic compounds. The concentration of phenolic compounds in mango pulp varies with species and/or variety, ranging from 200 to 3000 mg of gallic acid equivalents per 100 g of edible portion (Table 6), which exhibited a great antioxidant capacity [46] (Table 7). According to Palafox-Carlos et al. [34], the major phenolic compounds found in "Ataulfo" mango pulp are chlorogenic, gallic, protocatechuic, and vanillic acid. In addition, the authors mentioned that the gallic acid (39%) showed the highest contribution on antioxidant capacity followed by chlorogenic acid (21%), while major phenolic compounds in *M. indica* cv. Keitt pulp are gallic acid; mono-, tetra-, and penta-galloyl glucoside; hydroxybenzoic acid; and gallotannins [47]. The identified phenolic compounds coincide with those reported by Masibo and He [36] for mango pulp. Furthermore, Masibo and He [36] mentioned that the flavonoids are the most abundant polyphenols in our diet; unfortunately, information about flavonoid content in *Mangifera* species is scarce, and the values reported for some mango species ranged from 100 to 500 mg per 100 g of edible portion. Khoo and Ismail [48] have reported the presence of isoflavones as daidzein and genistein in *M. foetida*, *M. pajang*, and *M. odorata* pulps. These compounds can act as phytoestrogens, which may serve as health-promoting compounds in consumer's diet. *M. odorata* possessed the highest daidzein and genistein content (11.6 mg/100 g), followed by *M. pajang* (9.02 mg/100 g) and *M. foetida* (6.81 mg/100 g). In all cases daidzein content was higher than genistein content. According to the authors, the variability of the isoflavone content in mango fruits may be influenced by several internal and external factors [7]. Recently, López-Cobo et al. [49] in three mango cultivars (Keitt, Osteen, and Sensation) from *Mangifera indica* reported the presence of Alk(en)ylresorcinols and p-coumaric acid.

Mangiferin is a xanthone that exhibits great potential as antioxidant; it is a pharmacological active phytochemical and a natural polyphenolic antioxidant [50]. Mangiferin content of mango pulp ranged from 0.078 to 4 mg per 100 g. Furthermore, another phytochemical, lupeol, a well-known triterpene, is also found in several medicinal plants and fruits, including mango. The lupeol content in mango pulp from different mango species ranged from 0.006 to 0.181 mg per 100 g of edible portion. Some authors have mentioned that mangiferin and lupeol can act as an anti-inflammatory, antidiabetic, and cholesterol-lowering agent [50, 51].

Table 6 Bioactive compounds present in different ripe *Mangifera* species pulp

Mango specie	Total phenolic (mg/100 g)	Total flavonoid (mg/100 g)	Total isoflavones (mg/100 g)	Mangiferin (mg/100 g)	Lupeol (mg/100 g)	Total carotene (mg/100 g)	References
M. indica cv. Tommy-Kent	524[a]			4.4[b]		10.67	[3, 28, 50]
M. indica cv. Tommy Atkins	420[a]					0.006	[3, 61]
M. indica Ataulfo	80–174				0.010	0.030–0.060	[34, 44]
M. indica B Green				0.253	0.006		[43]
M. indica Dashehari				0.217	0.181		[43]
M. indica Chousa				0.078	0.023		[43]
M. caesia	2637	550					[46]
M. foetida	2918	550	6.81			4.81	[45, 46, 48]
M. laurina	144	176					[46]
M. odorata	257	202	11.6			3.95	[3, 46, 48]
M. pajang	7055	256	9.02				[48]
M. casturi	1538[a]						[3]
M. lalijiwa	595[a]						[3]
M. pentandra	676	118					[46]
M. longipetiolata	263	129					[46]
M. zeylanica	676[a]	118					[3, 46]

[a]Total soluble polyphenols
[b]Mango puree

Table 7 Antioxidant capacity by different methods in *Mangifera* species pulp

Mangifera species	ABTS	DPPH (%)	IC_{50} (mg/mL)	FRAP[a]	References
M. indica		73	10.21	0.64	[46]
M. indica cv. Tommy-Kent	39.20[a]	5.10[a]		0.37[a]	[3]
M. indica cv. Tommy Atkins	209.4[a]	1.46[a]		12.1[a]	[3]
M. caesia		92	8.14	0.66	[46]
M. foetida		17	43.22	0.62	[46]
M. laurina		56	13.32	0.64	[46]
M. odorata	88.30[a]	37	20.16	0.52	[3, 46]
M. pajang		19	38	0.49	[46]
M. zeylanica	150[a]	2.91[a]		13.15[a]	[3]
M. lalijiwa	130.8[a]	15.27[a]		6.94[a]	[3]
M. pentandra		56	13.27	0.65	[46]
M. longipetiolata		90	8.33	0.61	[46]
M. casturi	156[a]	13.54[a]		11[a]	[3]

[a]mmol kg^{-1} dry weight

The attractive color of mango pulp is mainly due to the presence of abundant β-carotene, but also, carotenoids are a potent antioxidant with several human health benefits [52]. Carotene content in *Mangifera* species ranged from 0.006 to 10.7 mg per 100 g of edible portion. *M. foetida* and *M. odorata* are *Mangifera* fruits which are considered as underutilized tropical fruits. But, the flesh of these mango species exhibited an important total carotene content as reported by Khoo et al. [45]; furthermore, carotene content of *M. foetida* (4.81 mg/100 g) and *M. odorata* (3.95 mg/100 g) is comparable to other commercial mangoes. Ajila et al. [53] mentioned that the yellow-orange flesh or ripened mango is attributable to the presence of carotenes. In this context, many of the wild mango species exhibited yellow-orange color pulp, indicating the possible presence of carotenes in their pulps [48].

Furthermore, Vilela et al. [54] mentioned that ripe mango pulp from *M. indica* cv. "Tommy Atkins" and other cultivars is a rich source of phytosterols and other lipophilic phytochemical (Table 8). The major groups of lipophilic compounds in mango pulp are sterols (947 mg/100 g DW) and fatty acids (949 mg/100 g DW), followed by the steryl glycosides (201 mg/100 g DW) [54]; some of these lipids have been termed as "bioactive lipids" because of their potential benefits for human health [55].

6.2 Phytochemicals Present in Mango Peel

Mango peel has been recognized as source for obtaining valuable components [56, 57] as phytochemicals (polyphenols, carotenoids) and vitamins (E and C) with different health-promoting properties [53], mainly by its antioxidant activity [34]. Moreover, mango peels are great source of proteins, carbohydrates, and dietary fiber [58–60], which make it suitable to be processed for value-added applications in functional foods

Table 8 Compounds identified in the lipophilic extracts of ripe mango pulp

Compound	*Mangifera indica* cv. Tommy Atkins (mg per 100 g db)
Fatty acids	940
Saturated	324
Dodecanoic acid	4
Tetradecanoic acid	26
Pentadecanoic acid	2
Hexadecanoic acid	228
Heptadecanoic acid	8
Octadecanoic acid	28
Eicosanoic acid	2
Docosanoic acid	8
Tetracosanoic acid	10
Pentacosadiynoic acid	8
Unsaturated	612
Hexadec-9-enoic acid	91
Heptadec-9-enoic acid	16
Octadeca-9,12-dienoic acid	48
Octadeca-9,12,15-trienoic acid	131
cis-Octadeca-9-enoic acid	205
trans-Octadec-9-enoic acid	122
Diacids	1
Long-chain aliphatic alcohols	104
Sterols	947
β-Sitosterol	571
Campesterol	149
Stigmasterol	68
Steryl glucosides	201
Others	195
α-tocopherol	64

Source: Vilela et al. [54]

and nutraceuticals [61] as discussed below. Currently, mango peel flour is used as functional ingredient in food products, mainly in bakery products [62].

Ediriweera et al. [63] reported that major lipophilic compounds identified in *M. zeylanica* peel (chloroform extract) were 1H-cycloprop[e]azulen-7-ol-decahydro-1,1,7-trimethyl-4-methylene, β-sitosterol, 9,12-octadecadienoic acid, caryophyllene oxide, phenol-3-pentadecyl, and α-tocopherol, among others. Also, Kim et al. [47] informed about the presence of unsaturated fatty acids as oleic acid, linoleic acid, and ethyl linoleate in peels from *Mangifera indica* L. cv. "Irwin."

Hassan et al. [60] reported in *Mangifera pajang* K. a content of TDF of 72% (SDF: 33.4% and IDF: 38.8%). Ajila et al. [64] stated mango peel to be a rich source of fiber, and 30–50% SDF and 50–70% IDF can be considered as a well-balanced range for maximum health benefits, due to each fraction that has different

physiological effects [65]. Similar results were reported in mango peels by Ajila and Prasada Rao [66] in "Badami" and "Raspuri" varieties (TDF ranged from 40% to 72% in both cases). Furthermore, DF has been associated with polyphenol compounds and called "antioxidant dietary fiber" [66].

With respect to ascorbic acid, green and ripe mango (*Mangifera indica* var. "Chokanan") peel contained an ascorbic acid of 109 and 52 mg per 100 g (DW), respectively [62]. Previously, Ajila et al. [53] reported an AA content of 34 and 39 mg per 100 g (DW) in raw and ripe peel of mango "Raspuri" and "Badami" cultivars, respectively. Also, Sogi et al. [61] informed an AA value of 75 mg/100 g (DW) in mango (*Mangifera indica* cv. "Tommy Atkins") peel. According to Ayala-Zavala et al. [37], mango peel exhibits great agro-industrial potential for use as functional ingredient or as anti-browning additive in food processing due to high content level of AA in the samples that act as natural antioxidant.

Tocopherol species are present in foods; α-tocopherol is most important to human health [67]. Ajila et al. [56] reported the α-tocopherol content for raw (10.4 mg ATE per 100 g DW) and ripe (23 mg ATE) mango peels from *M. indica* var. Badami. Nonetheless, Abbasi et al. [67] reported a high amount of vitamin E in peels (ranged from 7 to 43 mg per 100 g DW) than in pulp (ranged from 0.87 to 4.12 mg) of nine "Chinese" mango (*M. indica*) varieties, and they mentioned that the variations in results indicate that phytochemical composition in fruits may greatly be affected by genetic diversity within/among the cultivars and other factors as maturity stage and harvesting time. These high values show that the consumption of mango peel can contribute at the dietary needs for intake of vitamin E.

Concerning with total soluble polyphenol (TSP) compounds, García-Magaña et al. [58] reported TSP of 6.8 and 4.2 g GAE (per 100 g db), respectively, in "Ataulfo" and "Tommy Atkins" mangoes. Hassan et al. [60] informed a concentration of 9.8 g GAE (per 100 g DW) in Bambangan (*M. pajang* K.) mango. Furthermore, Sáyago-Ayerdi et al. [68] characterized the hydrolyzable polyphenol profile in the peels of the "Ataulfo" mango; they reported that mango peel may contain series of gallotannins between 5 and 13 units that possess high antioxidant activity. This means that the peel of the mango species can be considered an excellent source of antioxidants. Shieber et al. [50] reported the presence of mangiferin, quercetin, and kaempferol and their related conjugates in mango peel from *M. indica* cv. "Tommy Atkins." Prasad et al. [69] identified six phenolic compounds (pyrogallic acid, gallic acid, catechin, epicatechin, mangiferin, and rutin) from *M. pajang* peels. Blancas-Benitez et al. [70] informed about the presence of chlorogenic acid (82%) and vanillin acid (17%) in "Ataulfo" mango peel (*M. indica*). On the other hand, Barreto et al. [71] studied 16 varieties of mango (*M. indica*) peel, and they reported minimal differences in the profiles between cultivars; however, there was considerable variation in the amounts of the major phenolic compounds. These findings demonstrated that every mango species is genetically different and unique, as has been pointed in this study.

7 Other *Mangifera* Species with Potential for Consumption

Other commercially valued species that produced edible fruits are *Mangifera similis*, *M. quadrifida*, *M. griffithii*, *M. altissima*, *M. gebede*, *M. macrocarpa*, *M. rufocostata*, *M. flava*, *M. applanata*, *M. macrocarpa*, *M. duperreana*, *M. oblongifolia*, *M. kashiana*, *M gracilipes*, *M. sclerophylla*, *M. merilli*, *M. rumphii*, *M. rigida*, *M. quemanga*, and *M. superba*, among others [72]. The ripe fruits are acid-sweet and have a pleasant flavor [20]. Additionally, there are many cultivars or varieties from *M. indica* that exhibit a great potential for their commercialization. According to many authors, *Mangifera* family includes many wild *Mangifera* species [1, 2]. Unfortunately, nutrimental information about these mango species are scarce. Naik et al. [73] opine that it is the large variability that has hindered the production of the commercial varieties on a large scale. However, it is true that this large biodiversity has not been exploited to the full potential [19].

8 Conclusion

Evidence showed that some of the wild *Mangifera* species such as *M. caesia*, *M. foetida*, *M. odorata*, *M. casturi*, *M. lalijiwa*, *M. zeylanica*, *M. sylvatica*, and others are healthy fruits to consume specially from the nutrimental viewpoint and are similar or better nutrimental source than the popular *M. indica*. In general, the commercially (*M. indica*) and wild mango species can be considered for many purposes including for processing and for consumption because mango may be considered an excellent source for improving nutrition. However, enhanced knowledge of the status of such species is necessary for the conservation of these valuable species. Also, this chapter offers a better understanding of the nutrimental and functional potential of these fruit species.

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