Nutritional and medicinal values of *Mangifera indica* L. fruit

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**ABSTRACT**

*Mangifera indica* L. (Mango, Anacardiaceae) is a popular tropical evergreen tree known for its nutritional and medicinal values. It is native to India and Southeast Asia and is known as the “king of fruits” in India and the Philippines. It is considered important in Ayurveda and other systems of medicine. Mango fruit is unique in its taste, colour, aroma, and nutritional qualities. Mangoes are a rich source of polyphenols (Mangiferin, Gallotannins, Quercetin, Isoquercetin, Ellagic acid, Glucogallin, Kaempferol, Catechins, Tannins, and the unique Xanthonoid), phenolic acids (Hydroxybenzoic acids- Gallic, Vanillic, Syringic, Protocatechuic, and p-Hydroxybenzoic acids, Hydroxycinnamic acid derivatives-p-Coumaric, Chlorogenic, Ferulic, and Caffeic acids), flavonoids (β-carotene, α-carotene, β-cryptoxanthin, and Lutein), Vitamin A, Vitamin-B6 (pyridoxine), Vitamin-C, Vitamin-E, Carbohydrates, Amino acids, Organic acids, micronutrients (Potassium, Copper), fats (Omega-3 and 6 polyunsaturated fatty acids), dietary fibre and certain volatile compounds. About 25 different types of carotenoids have been isolated from the fruit pulp, which contributes to the colour of the fruit. Phytochemical and nutrient content may vary depending on the cultivar. Mangoes possess potential medicinal properties such as antioxidant, gastro-protective, anti-inflammatory, analgesic, immunomodulatory, anti-microbial, and many more. Mango fruit is an abundant source of all essential nutrients and phytochemicals; it could be utilized as a nutritional supplement in the prevention and cure of several diseases. A comprehensive report on the nutritional and medicinal properties of fruit is presented below.

**Keywords:** mango; fruit; polyphenols; phenolics; flavonoids; carbohydrates; proteins; fats vitamins; minerals; medicinal properties

1. Introduction

*Mangifera indica* L. (Mango), “the king of fruits”, is an evergreen tropical fruit tree comprising about 69 species belonging to the family Anacardiaceae. The tree is indigenous to India and Southeast Asia[1]. It is the national fruit of India and the Philippines and the national tree of Bangladesh[2]. It is a common fruit tree cultivated on about 3.7 million hectares worldwide. More than 1000 varieties of mangoes are commercially cultivated in 87 countries. For hundreds of centuries, mangoes have been grown in the Himalayan region, Burma, and Bangladesh. For thousands of years, many cultivars have been vegetatively propagated in India[3]. Birbal Sahni Institute of Palaeobotany, Lucknow, has excavated 60 million-year-old fossilized mango leaf compression in Palaeocene sediments in Damalgiri, Meghalaya, and named it *Eomangiferophyllum damalgiriensis*[4]. Extensive anatomical and morphological studies on the present genus and the fossilized material have revealed that North-East India was the centre of the origin of mangoes. It spread to Southeast Asia later. Today, they are extensively grown in Central America[5], Africa[6], Australia[7],...
and Europe\textsuperscript{8}. The main mango-producing countries in the world are India, Pakistan, Mexico, Brazil, Haiti, the Philippines, and Bangladesh.

Mango is a delicious fruit and is hence called “food for gods”. It is rich in prebiotic dietary fibre, vitamins A and C, minerals, and polyphenolic flavonoid antioxidant compounds. According to Habib et al.\textsuperscript{9} and Lauricella et al.\textsuperscript{10}, mangoes provide 64–86 calories of energy. It contains sugar, protein, fats, and other nutrients. Mangoes are eaten fresh as a dessert and processed as pickles, jams, jellies, sauces, nectar, juices, cereal flakes, and chips\textsuperscript{11}. Generally, mangoes are edible at all stages of development, from the tiny set fruit to the mature ones. The nutritional value of mangoes depends on the variety and the developmental stage\textsuperscript{12}. In traditional systems of healing Mango, fruits are used to cure sunstroke, ophthalmia, eruption, intestinal disorder, infertility, and night blindness. The oil used in eczema\textsuperscript{13–15}. Seed kernel is used in hemorrhages and bleeding hemorrhoids. Seed can be applied to ulcers, bruises, leucorrhoea, and burns to treat diabetes, heartburn and vomiting, asthmatic cough, helminthiasis, chronic diarrhea, dysentery, menorrhagia, and hemoptysis\textsuperscript{16}. The entire fruit has several phytochemical and nutritive constituents. Consumption of mango fruit along with a balanced diet can enhance the health status of an individual. The nutritional and medicinal properties of fruit peel, pulp, and seed are discussed below.

2. Description of the fruit

A single mature mango tree can produce as many as 2000 to 2500 ripe fruits. Mango fruit is a drupe. The length of the fruit ranges from 2.5 cm to more than 30 cm. The pericarp, or peel, is waxy, smooth, thick, and aromatic. When unripe, the peel is light green to dark green, and as it ripens, the colour changes from yellow to reddish pink (\textbf{Figure 1}).

![Figure 1. Entire fruit of Alphonso variety of mango.](image)

The aroma of the fruit ranges from a “turpentine” odour to a pleasant fragrance, depending on the cultivar. The shape of the mango may be oblong or sub-reniform. The mesocarp is the fleshy, juicy, sweet, and edible portion of the fruit. The pulp is yellow to dark orange in colour\textsuperscript{17}. The endocarp is hard, woody, stony, fibrous, flattened, and longitudinally ribbed in nature (\textbf{Figure 2}). It is pale yellowish-white in colour and contains a solitary seed. The seed is generally monoembryonic or polyembryonic.
3. Phytochemicals in the fruit

The nutritional and medicinal values of the fruit are mainly due to the phytochemical constituents. These phytochemicals also contribute to the taste, aroma, and flavour of the fruit. The fruits also yield a resin that contains mangiferin, mangiferic acid, resinol, and maniferol. The fruit is economically and nutritionally important and, hence, recommended by health organizations.

3.1. Phytochemicals in pulp

The edible part of mango contains an array of compounds such as polyphenols, phytosterols, isoflavones, and carotene. β-carotene is abundantly present in the pulp and is responsible for its attractive colour. β-carotene, a potent antioxidant, has several health benefits. The carotene content in the fruit is approximately 10.7 mg per 100 g of edible portion. Dietary antioxidants, such as phenolic compounds, are present. However, the concentration depends on the species and variety. Major phenolic compounds such as chlorogenic, gallic, protocatechuic, and vanillic acids were reported by Palafox-Carlos et al. Khoo and Ismail have reported the presence of isoflavones such as daidzein and genistein. These isoflavones act as phytoestrogens. Recently, 34 phenolic acid derivatives have been reported. Rosmarinic acid was detected in the pulp at different stages of ripening. Flavonoids (quercetin, kaempferol, catechins, anthocyanins, rhamnetin, and tannic acid) and the class of xanthones, mangiferin, are reported in mango. Major phenolic compounds such as chlorogenic, gallic, protocatechuic, and vanillic acids were reported by Palafox-Carlos et al. Khoo and Ismail have reported the presence of isoflavones such as daidzein and genistein. These isoflavones act as phytoestrogens. Recently, 34 phenolic acid derivatives have been reported. Rosmarinic acid was detected in the pulp at different stages of ripening. Flavonoids (quercetin, kaempferol, catechins, anthocyanins, rhamnetin, and tannic acid) and the class of xanthones, mangiferin, are reported in mango. Rosmarinic acid was detected in the pulp at different stages of ripening.

3.2. Phytochemicals present in Mangifera indica peel

Mango peel is a source of valuable constituents such as polyphenols, phenolic compounds such as vanillic acid, gallic acid, ferulic acid, coumaric acid, chlorogenic acid, pyrogallic acid, syringic gallotannins catechin, epicatechin, methyl gallate ester, methyl gallate, galloyl glucose, theogallin, protocatechuic, mangiferin, rutin, carotenoids, vitamins E and C. Schieber et al. reported the presence of flavonoids, quercetin, and kaempferol. Chlorogenic acid (82%) and vanillin acid (17%), according to Benitez et al., were reported to have antioxidant activity. A recent comparative study shows that the peels contained significant polyphenols and had the highest antioxidant activity when compared to the pulp. Moreover, mango peel is a good source of dietary fibre, proteins, and carbohydrates. Hence, it finds its application in the food and nutraceutical Industries. Mango peel flour is used in bakery products. Unsaturated fatty acids such as oleic acid, linoleic acid, and ethyl linoleate are also present in the peels.
3.3. Phytochemicals present in *Mangifera indica* seed

The mango seeds are rich in fatty acids, sterols, and triterpenoids. Long-chain hydrocarbons and fatty acids include linoleic, octadecanoic acid, linolenic, eicosanoic acid, monounsaturated fatty acid, hexadecanoic acid, and arachidonic acid. Sterols such as sitosterol, campesterol, and stigmasterol, \( \alpha \)-pinene, myrcene, \( \beta \)-pinene, and limonene are the chief triterpenes and triterpenoids. The seeds of mango fruit are also considered promising sources of polyphenols\(^{[28]} \). Polyphenols and phenolic acids include ascorbic acid, mangiferin, quercetin, and gallic acid\(^{[43]} \).

4. Nutrients in *Mangifera indica* fruit

According to Masibo and He\(^{[28]} \), the fruit of mango is unique because all the parts—peel, pulp, and kernel—are nutritionally significant. Mango fruit has a high amount of water (approximately 86%), carbohydrates (25%), proteins (5.11%), and lipids (2.7%). The seed kernel is rich in carbohydrates, protein, fats, vitamins, and minerals. The quantity of nutrients in the fruit and kernel depends on the cultivar, climatic conditions, ripening and harvesting times, and the type of soil. It is estimated that only 3% of the pulp has important nutrients when compared to the seed kernel, which has 20–50 times more nutrients than the pulp (Figure 3).

![Figure 3. Nutrient’s composition in *Mangifera indica* fruit.](image)

* Adapted from Patel and Kheni\(^{[44]} \), Shobana and Rajalakshmi\(^{[45]} \), Tokas et al.\(^{[46]} \) and Yatnatti et al.\(^{[47]} \).

4.1. Dietary fibre

The fruit pulp is very nutritious and easily digestible due to its rich source of dietary fibres\(^{[48]} \). The dietary fibre in the fruit regulates glucose and lipid levels in the blood\(^{[49]} \). Barbosa Gámez et al.\(^{[50]} \) reported a higher total dietary fibre content in ripened fruits than in unripe ones.

4.2. Vitamins and minerals

Vitamins and minerals contribute a major part of the nutrient components of fruits; these compounds are essential for various biochemical and physiological processes in the body. Vitamins are organic compounds that are essential nutrients for normal cell functions, growth, and development in humans. Vitamins help in the breakdown and assimilation of proteins, carbohydrates, and fats. Most vitamins—A, C, D, E, K, B\(_1\), B\(_2\), B\(_3\), B\(_5\), B\(_6\), B\(_7\), B\(_9\), and B\(_12\) (except Vitamin D)—cannot be synthesized in our body and have to be acquired only through food intake. Major minerals required in larger quantities include phosphorus, magnesium, potassium, sodium, calcium, and chloride. In addition, trace elements such as iron, fluoride, iodine, cobalt, chromium, copper, manganese, molybdenum, selenium, and zinc are required for the normal functioning of the body\(^{[51]} \).
The mango fruit is a good source of calcium, magnesium, potassium, zinc, and phosphorus\textsuperscript{[52]}. The unripe fruit is rich in calcium, magnesium, potassium, and phosphorus (Figure 4).

![Figure 4. Mineral composition of Mangifera indica fruit.](image)

* Adapted from Patel and Kheni\textsuperscript{[44]}, Shobana and Rajalakshmi\textsuperscript{[45]}, Tokas et al.\textsuperscript{[46]}, Yatnatti et al.\textsuperscript{[47]}, and Fowomola\textsuperscript{[53]}.

The mango varieties vary greatly in vitamin C content\textsuperscript{[51]}. Unripe mango is rich in all vitamins except vitamin B\textsubscript{12} (Table 1). On the other hand, the seed kernel contains vitamins A, K, E, C, and B\textsubscript{12}. It is also rich in minerals such as potassium, calcium, iron, sodium, phosphorous, magnesium, zinc, and manganese\textsuperscript{[54]}.

<table>
<thead>
<tr>
<th>Vitamins mg/100g</th>
<th>Ripe peel</th>
<th>Pulp</th>
<th>Unripe mango</th>
<th>Seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A</td>
<td>12</td>
<td>725</td>
<td>846</td>
<td>10</td>
</tr>
<tr>
<td>Vitamin B\textsubscript{2}</td>
<td>-</td>
<td>0.038</td>
<td>0.1</td>
<td>0.03</td>
</tr>
<tr>
<td>Vitamin B\textsubscript{3}</td>
<td>-</td>
<td>0.669</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Vitamin B\textsubscript{5}</td>
<td>-</td>
<td>0.160</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Vitamin B\textsubscript{1}</td>
<td>-</td>
<td>0.028</td>
<td>0.1</td>
<td>0.08</td>
</tr>
<tr>
<td>Vitamin B\textsubscript{6}</td>
<td>-</td>
<td>0.119</td>
<td>0.1</td>
<td>0.19</td>
</tr>
<tr>
<td>Vitamin K</td>
<td>-</td>
<td>0.042</td>
<td>0.0042</td>
<td>0.59</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>52</td>
<td>36</td>
<td>46</td>
<td>0.56</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>-</td>
<td>1.12</td>
<td>1.8</td>
<td>1.3</td>
</tr>
<tr>
<td>Foliate</td>
<td>-</td>
<td>0.0043</td>
<td>0.014</td>
<td>-</td>
</tr>
<tr>
<td>Vitamin B\textsubscript{12}</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.12</td>
</tr>
</tbody>
</table>

*Adapted from Patel and Kheni\textsuperscript{[44]}, Shobana and Rajalakshmi\textsuperscript{[45]}, Tokas et al.\textsuperscript{[46]}, Yatnatti et al.\textsuperscript{[47]}, and Fowomola\textsuperscript{[53]}.

### 4.3. Proteins and amino acids

Mangoes, like any other fruit, contain a low protein content. The amino acid composition also varies among cultivars and maturation levels\textsuperscript{[55]}. The amino acids Alanine, Arginine, Glycine, Leucine, Isoleucine, and Serine have been detected in considerable amounts in the ripened mangoes, while all other amino acids are present in trace quantities only\textsuperscript{[56]}. The amino acids that cannot be synthesized in humans are phenylalanine, tryptophan, methionine, valine, lysine, threonine, leucine, isoleucine, and histidine. Usually, seeds are rich in protein. The mango kernel has approximately 20 times more protein than the pulp. According to Fowomola\textsuperscript{[53]}, except for tryptophan, all eight other essential amino acids are present in the kernel (Figure 5). Hence, mango seeds are considered an excellent supplementary food.
Figure 5. Essential and non-essential amino acid composition of Mangifera indica seed (g/100g seed).
* Adapted from Fowomola[53].

4.4. Carbohydrates

The ripened fruit contains glucose, fructose, sucrose, starch, and pectin. Sucrose is the major sugar in the pulp[57]. The mango pulp has approximately 17% carbohydrate. However, the seeds contain a higher reserve of carbohydrates than the unripe mango. During ripening, starch gets hydrolysed into sugars, and hence, at the ripened stage, the pulp is rich in fructose and glucose[58]. However, the composition of the fruit depends on the cultivar[59], climatic conditions, ripeness at harvest[60], and post-harvest storage of the fruits.

4.5. Lipids

The lipid content of the unripe mango peel and seeds is considered to be higher than that of cocoa butter. The ripe mango has a lower fat content. The major fatty acids present in the kernel are oleic, linoleic acid, palmitic, stearic, arachidic, lignoceric, and behenic acids, which are present in lower concentrations[61]. Thus, mango seed fats can be an alternative to cocoa butter. Triglycerides are a greater component of the pulp than monoglycerides and diglycerides. During ripening, the levels of unsaturated fatty acids and omega-6 and omega-3 fatty acids seem to increase, and hence mango is a rich source of essential fatty acids[62].

4.6. Organic acids

Organic acid is essential for flavour constituents that are responsible for fruit quality, organoleptic properties, and the acidity of the fruit[63]. Certain varieties are reported to contain α-ketoglutaric, ascorbic, oxalic, and tartaric acids at lower concentrations, while succinic and malic acids were also detected at higher concentrations in certain varieties[59]. However, citric acid and malic acid are the major organic acids found in the pulp[56].

5. Ethno medicinal uses of Magnifera indica

According to Ayurveda, Vata, Pitta, and Kapha Doshas are vital energies that govern, regulate, and control the physical and mental well-being of a human. It is used to treat vitiated conditions of the Vata and Pitta.

Ripe mango fruit is a restorative tonic and is used for heat stroke. The fruit is sweet, refrigerant, cardiotonic, haemostatic, aphrodisiac, emollient, and laxative. Anorexia, dyspepsia, uterine, haemorrhages; emaciation, and anemia are also treated with the fruit. The unripe fruits are acidic, acrid, refrigerant, antiscorbutic, digestive, and carminative. The seeds are refrigerant, sweet, astringent, and acrid. They are used in treating cough, asthma, heart problems, ulcers, bruises, leucorrhoea, menorrhagia, diabetes, intestinal worms, constipation, haemorrhages, haemorrhoids, haemostatic, dysentery, chronic diarrhea, vomiting, and uterine
tonics. It is also used for liver disorders, tooth diseases, and as an antidote for poisonous scorpion and honeybee stings\textsuperscript{[13,14]}.

6. Medicinal properties of \textit{Mangifera indica}

The polyphenols present in mangoes exert health benefits\textsuperscript{[64]}. Furthermore, 25 diverse carotenoids have been identified that contribute to the colour and antioxidant properties of the fruit. The other antioxidant compounds are flavonoids (catechins, quercetin, kaempferol, rhamnetin, anthocyanins, and tannic acid) and xanthones like mangiferin\textsuperscript{[26]}.

6.1. Anti-oxidant

The mango peel is reported to possess antioxidant activity\textsuperscript{[65]} which may be because of the phenolic content that confers the activity. Reactive oxygen species have a strong oxidizing effect that induces damage and brings about changes in the structure of proteins, lipids, and DNA. The antioxidants in the mango peel seem to scavenge the various harmful free radicals\textsuperscript{[42]}. Other studies proved that it also acted as an iron chelator and offered protection against iron-induced oxidative damage.

6.2. Antiviral activity

Mangiferin in the fruit is reported to have antiviral activity against \textit{Herpes simplex} virus type 2. Mangiferin inhibits the late replication of HSV-2 but does not directly inhibit it. However, HSV-1 replication inhibits and antagonizes the effects of HIV\textsuperscript{[66,67]}.

6.3. Antimicrobial activity

Mango extracts are reported to exhibit antibacterial and antifungal activity. The extracts were effective against gram-positive and gram-negative bacteria and \textit{Candida albicans}\textsuperscript{[68]}. Gallotanins and mangiferins are responsible for their activity\textsuperscript{[69]}. \textit{Alternaria alternata} was inhibited by aqueous, ethanol, and methanolic extracts of mango\textsuperscript{[70]}. A recent study shows that the mango peel extracts, both aqueous and ethanolic, had significant antibacterial and antifungal activity against \textit{Escherichia coli}, \textit{Staphylococcus aureus}, \textit{Bacillus cereus}, \textit{Pseudomonas aerogines}, and \textit{Candida albicans}\textsuperscript{[71]}.

6.4. Antidiarrhoeal activity

The anti-diarrhoeal activity of seed extracts (methanol and aqueous) was studied in diarrhea-induced mice. Under experimental conditions, castor oil and magnesium sulphate were used as diarrhoeal agents. The methanolic extract had significant antidiarrhoeal activity. The kernel aqueous extract also exhibits anti-diarrheal activity\textsuperscript{[72,73]}.

6.5. Anti-inflammatory action

The phytochemicals present in mango have a significant anti-inflammatory action on pathological disorders\textsuperscript{[74,75]}. Inflammatory bowel diseases are associated with the risk of colon and rectal cancers\textsuperscript{[76]}. Mango extracts exert an anti-inflammatory action in experimental murine models of ulcerative colitis\textsuperscript{[77]}. The mango mesocarp extract, rich in polyphenols, reduced the inflammatory response in colitis-induced mice\textsuperscript{[78]}. An ethanolic extract of the seed kernel exhibited significant anti-inflammatory activity in acute, subacute, and chronic cases of inflammation.

6.6. Anti-diabetic effect

Phytochemicals in mangoes have an anti-diabetic effect. Diabetes mellitus is a metabolic disorder associated with hyperglycemia. Mango mesocarp extracts produced a significant hypoglycemic effect in streptozotocin (STZ)-induced diabetic rats\textsuperscript{[79,80]}. Furthermore, Gondi et al.\textsuperscript{[81]} showed that the administration
of different doses of exocarp extracts to diabetic rats resulted in a significant decline in blood glucose levels.
The anti-diabetic effect of exocarp extracts was due to the inhibition of α-amylase and α-glucosidase\cite{82}.

6.7. Anticancer activity

An ethanolic extract of mango exocarp induced apoptosis in human cervix adenocarcinoma HeLa cells\cite{83}. This activity may be due to quercetin-3-O-arabino-pyranoside, mangiferin-gallate, quercetin 3-O-galactoside, isomangiferin gallate, and mangiferin present in the exocarp. The aqueous extract of mango mesocarp exerted antitumor activity in human colon adenocarcinoma cell lines and colorectal cancer in rodents\cite{84}. Abdullah et al.\cite{85} reported that an ethanolic extract of mango kernel induced cell death in both oestrogen-positive and oestrogen-negative breast cancer cell lines. Urushiol in the fruit peel may induce an allergic reaction\cite{86}. Percival et al.\cite{87} found that whole mango juice exerted anticancer activity by inhibiting the cell cycle in the G0/G1 phase. Mangiferin may interfere with the assembly or functioning of microtubules\cite{88,89}. The other possible mechanisms of mangiferin are inhibition of telomerase\cite{29} and an increase in cellular apoptosis. Kim et al.\cite{83} reported the anti-proliferative activity of mango peels and pulp.

6.8. Anti-hemorrhagic and anti-dermonecrotic activity

The seed kernel ethanolic extract of mango exhibited an inhibitory effect on the caseinolytic and fibrinogenolytic activities of Viper and Cobra venom. The molecular docking studies revealed that mangiferin bound to the snake venom metalloproteinases and inhibited the venom enzymatic activity and tissue necrosis\cite{90}.

6.9. Hepatoprotective activity

Hepatoprotective activity was found in the ethanolic extracts of seed kernels\cite{91}. Hepatoprotective activity was evaluated against liver injury in rats induced by carbon tetrachloride (CCl4). Three polyphenolic principles, 1, 2, 3, 4, 6-penta-O-galloyl-β-D-glucopyranose (PGG), methyl gallate (MG), and gallic acid (GA), caused the hepatoprotective activity.

7. Conclusion

Mango fruit peel, pulp, and seed contain essential amino acids, proteins, vitamins, carbohydrates, fatty acids, dietary fibres, carotenoids, and phenolic compounds that contribute to gastrointestinal health. Mango peels are rich in antioxidants and hence possess free radical scavenging activity, which could prevent cancer. The fruit has anti-inflammatory action, which can prevent inflammatory bowel diseases. The seeds are reported to contain hepatoprotective action. Mangoes are rich in health-benefit constituents and are rightly called the “king of fruits”. Regular consumption of mangoes, either in an unripe or ripened state, can prevent or cure several health-related diseases, and hence it could be utilized as a supplementary food in nutraceuticals. Further research on the various phytochemicals and their pharmacological activity will shed more light on their significance in human health.

Conflict of interest

The authors declare that there is no conflict of interest.

References


