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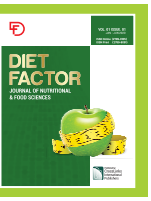

Review Article

Potential Health Benefits, Agro-Wastes and Industrial Byproducts of Mango (*Mangifera Indica* Linn)

Afrah Jabeen[1] and Madiha Khan Niazi[2*]

[1]University of Veterinary and Animal Sciences, Lahore, Pakistan.
[2]University Institute of Diet and Nutritional Sciences, Faculty of Allied Health Sciences, The University of Lahore, Pakistan

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***Corresponding Author:**
Madiha Khan Niazi
University Institute of Diet and Nutritional Sciences, Faculty of Allied Health Sciences, The University of Lahore, Pakistan
dr.madihaniazi@gmail.com

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ABSTRACT

Mango (*Mangifera indica Linn*) fruit is widely consumed around the world, but mango leaves are gaining popularity due to their numerous medicinal effects. Mangoes (*Mangifera indica L.*) account for about half of all tropical fruits produced worldwide, and their net output is predicted to rise rapidly over the next two decades due to improved agro-industrial technologies, the marketing of new varieties, and demand from health-conscious customers. Mango production costs are far higher than those of its edible part due to the management, recycling, and disposal of agricultural wastes and food by-products; this is even before factoring in the costs related with the environment and human health. Raw mangoes are commonly used in salads and pickles. Because mango has the unique capacity to change sour food into sweet, its prospective benefits as a potent antioxidant and sweetness enhancer are encouraging. Mango fruits, fruit pulp, and leaves were used in Ayurvedic medicine for hundreds of years to treat a wide range of health problems and diseases. According to chemical research, mango and mango leaves include a variety of polyphenolic antioxidants and micronutrients. This review looks into mangiferin and parts of mango, which have multiple health advantages for human health and illness prevention.

INTRODUCTION

Mango (*Mangifera indica linn*) is known as the "King of all fruits" due to its rich, juicy, aromatic odor and pleasant flavor, with sweetness and acidity well balanced. Mango fruit (*Mangifera indica*) variants varies in taste, size, and form; this is mostly determined by the mesocarp section of each cultivar, which is why all mango cultivars taste slightly different [1,2]. The distinct flavor of mangoes is primarily defined by the carbohydrates and organic acids present in the fruit while it is unripe [3]. The carbohydrates included in the fruit are in starch form, which when ripened changes into sugars like fructose, glucose, and sucrose. Different mango cultivars' storing and ripening techniques may also influence their biochemical and physiological properties, as described by Bhardwaj *et al.*, who conducted a study on three mango varieties and discovered one with a higher vitamin C concentration than the other two forms of the same fruit [7]. The tree is medium to large (10-40 m tall), evergreen, with a symmetrical, circular canopy that can be either upright and open or low and packed. Bark is often smooth and ranges in colour from dark grey-brown to black, slightly broken on the surface, or subtly fissured, and peels off in haphazard, thick chunks. The tree produces a dense network of superficial feeder roots in addition to a long, unbranched tap root that can reach a height of 6 to 8 metres. An eighteen-year-old mango tree's effective root system can be observed to extend up to 7.5 metres in the

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lateral direction [8]. The leaves are 15–45 cm long and are simply placed alternately. The petiole is always inflated at the base and ranges in length from 1 to 12 cm. Variable leaf shapes include ovate, obovate-lanceolate, oval-lanceolate, lanceolate, oblong, linear-oblong, and roundish-oblong [9]. While the under surface is glabrous light green, The upper surface is dark green and glossy. The fruit is a roughly compressed, fleshy drupe with a wide range of variations [10]. This review aimed to discuss the ethnomedicinal uses of mango to evaluate its health effects in addition to the agricultural wastes and industrial by-products of mango.

ETHNOMEDICINAL USES

For thousands of years, mangos have been utilized for a variety of ethnomedical purposes, using various portions of the fruit [11]. Bark and roots are used as a vulnerary, anti-emetic, anti-inflammatory, styptic, astringent, acrid, and refrigerant. Leaves are used as vulnerary, constipating, styptic, astringent, and refrigerant. Additionally, they help with vitiated disorders such as hiccups, coughing, hyperdipsia, burning sensations, and diarrhea. Burns and scalds can benefit from the ash from burned leaves. Leaves relieve throat ailments caused inhaling the smoke produced by burning leaves. Flowers are used as vulnerary, styptic, haematinic, astringent, and refrigerant. Pitta-vitiated illnesses such as hemorrhages, hemoptysis, wounds, ulcers, anorexia, dyspepsia, uroedema gleet, bladder catarrh, diarrhea, chronic dysentery, and anemia can benefit from the use of dried flowers. Fruits are Rounded, have antiscorbutic and carminative properties. They are helpful for vaginopathy, eruptions, urethrorrhea, and dysentery ophthalmia. Ripe fruits are laxative, sweet, emollient, cardiotonic, hemostatic, aphrodisiac, and tonic. Stone: The seed kernel is high in gallic acid and protein (8.5%). The conditions of cough, helminthiasis, hemoptysis, hemorrhoids, ulcers, menorrhagia, diabetes, heat burn, and vomiting can all benefit from it.

CHEMICAL PROFILE OF MANGO FRUIT

A healthy diet should contain bioactive components that help prevent disease. Mango, a 'functional food', contains macronutrients and micronutrients, which are necessary for health promotion and illness prevention. Its high bioactive components can be used as nutraceuticals or active ingredients in the food and pharmaceutical industries [12].

Nutrients in Mango

Macronutrients

Mango flesh varies little between kinds, with flour made from mango kernels containing protein, fat, fiber, and starch per kilogram [13]. Mango seed kernels have a low protein content but high quality necessary amino acids [14]. The fat content ranges from 6 to 12%, with high quantities of stearic and oleic acids suited for food industry application [15]. The European Union has authorized mango seed fat as a substitute for cocoa butter. Dietary fiber (DF) consumption provides several health benefits for both the intestine and the whole person [16].

Micronutrients

Mango flesh is low in critical elements such as calcium, potassium, magnesium, iron, and zinc [17]. However, mango peel includes a high concentration of these minerals. Mango contains provitamin A carotenoids, including β-carotene, which is needed for vitamin A insufficiency. Mango intake can aid with public health issues [18]. The preservation conditions of the flesh, together with the presence of phenolic chemicals, protect it from ascorbate oxidation [19].

Bioactive Compounds

Natural chemicals contained in many fruits and seeds have been widely researched in recent years due to their beneficial health effects [20]. Table 1 shows that mango fruit contains a significant amount of bioactive chemicals [21].

Table 1: Bioactive Components Present in Different Parts of Mango Fruit

Age Group	Compound Names	Part
Vitamins	dehydroascorbic and ascorbic acids	Flesh
Phenolic Acids	gallic acid, caffeic acid	Flesh, Peel, Seeds, Kernel
Carotenoids	β-carotene, violaxanthin, mutatochrome	Flesh
Polyphenols	mangiferin, isomangiferin, quercetin	Flesh, Seed, Peel
Other Phenols	mangiferin, isomangiferin, quercetin	Peel, Sap
Antioxidant Minerals	mangiferin, isomangiferin, quercetin	Flesh, Peel, Seed
Terpenoids	α-pinene, cisocimene, β-pinene, β-myrcene, trans-ocimene, terpinene	Flesh, Peel, Sap
Fibre	-	Peel, Seed, Flesh

AGRO-WASTES AND INDUSTRIAL BY-PRODUCTS

Food production-related primary production, industrial transformation, marketing, and funding are all integrated in agribusiness. Several food technologies are typically used to modify raw foods in order to make them easier to consume in the end and to increase their point of sale added value. Agronomic wastes and byproducts from numerous auxiliary supply chain operations have an impact on farmers' economies, the environment, and public health. Waste is defined as items utilized as animal feed or leftovers from food processing [19]. It also covers any potentially reusable, safe substance that is lost, thrown away, or biodegrades at any stage of its manufacture but is not meant for human consumption [22]. According to the European Union, residue is anything that remains after a procedure but is not the final (primary) result. Waste is defined as any material or object that the holder discards,

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plans to discard, or is forced to discard [23]. Taking these definitions into account, Figure 1 explains the different types of mango residues that have the potential to be reused as well as how they are produced. For instance, it shows that discarded Mango peels and seeds are disposed of at the retail and commercial trade levels, while full mangoes are disposed of at the industrial, packaging, and consumer levels. Many companies prioritize the reuse, recover, and recycle, which have led to the development of more profitable and sustainable procedures with little to no ecological impact. But some residues are viewed by food makers as "invisible" or "not viable," thus neither appropriate procedures for their removal nor inclusion in their economic predictions are planned for them [23]. This means that commercial mango processing into juices/nectars, pulp that has been freshly cut, purees/jams, and powders/chutneys produces a lot of wastes (Figure 1) without realizing how much nutrients and phytochemicals are present that could be valuable to the nutraceutical industry [24-26].

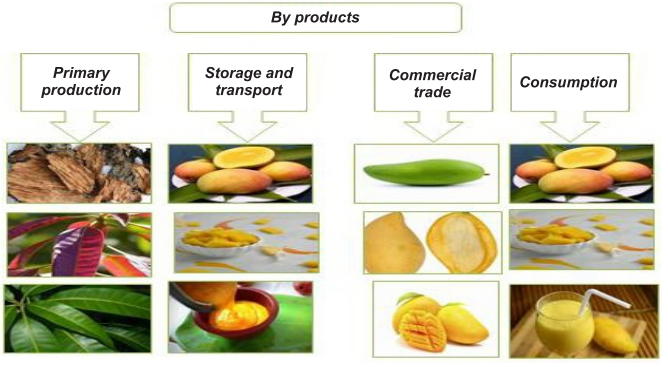

Figure 1: Mango Agro-wastes and Industrial By-products

Impacts of Generating Mango Wastes and By-products

Achieving a positive transformation towards the recovery and recycling of Mango wastes and byproducts demand an awareness of the economic and environmental effects associated with them. These elements and the current state of study on the subject are briefly covered here.

Economic Impact

Mango production and consumer demand around the world provide farmers a growing market, but there is also a pressing need for convenient crop management and creative pre- and post-harvest techniques to meet this need. Regardless of cultivar, the fundamental physiological parameters for effective mango management are the same; however, pre- and post-harvest, each country has different processes and marketing strategies [27]. For example, waste occurs at the retail and consumer levels in low-income countries, but waste is created just after harvest in high-income countries [28]. Mango quality and safety are influenced by various aspects across the supply chain, including ripening immediately before purchase, sanitization procedures, on-site packing, shipping, and storage conditions [29, 30]. The agronomic stage wastes and by-products must be assured to be reduced in order to boost the profitability of the mango agroindustry while reducing its influence on pollution. Before mangoes reach consumers, postharvest losses are believed to be between 25 and 40 percent; nevertheless, the waste produced by the latter is equally significant, ranging from 33 to 43 percent. Mango production costs are far higher than those of its edible part due to the management, recycling, and disposal of agricultural wastes and food by-products; this is even before factoring in the costs related with the environment and human health. However, there is no specific report accessible for mangos [31].

Environmental Impact

A large amount of organic matter, or biomass, is wasted during the production and processing of mangos. This biomass can be used as a renewable energy source and for a number of other environmentally beneficial applications that are not yet generally adopted. Reusing waste and byproducts to make new products or even the same product is one of the key strategies recommended by reduction, reuse, and recycling approach to managing agricultural waste. Recycling the same resource also reduces waste generation by preventing the exploitation of new resources. Key unit processes along the mango supply chain emit greenhouse gases [32]. However, biofuel (made through anaerobic digestion) or bio-oil (produced through controlled pyrolysis) derived from mango lignocellulosic biomasses can be used to replace some fossil fuels, hence reducing air pollution [33, 34]. Australia's water footprint in its supply chain exceeds 40 Gl of green and blue water, with no verified return flow to the local source. In 2016, Australia was rated 42nd in the world for mango production [35]. However, cellulose nanocrystals that have been separated from MS/stone may be utilized as eco-friendly materials—possibly even in the treatment of wastewater [36]. A biorefinery facility for mango processing waste was designed to recover multiple coproducts, specifically pectin and MS oil, from the trash. This plant can be lucrative with little initial investment and high returns [37, 38]. However, in addition to technology and financial incentives, a sustainable mango agribusiness also needs a shift in producer-to-consumer attitudes and mindset.

Research and Development (R&D)

Mango waste and byproducts have sparked interest in industry and science [39], with a notable increase in research publications and patents since 2006. Research on *M. indica L.* leaves and seeds has increased significantly [40,41], with papers on bark and pulp/flesh coming in a close second. The research focuses on enhanced

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agronomic methodologies, phytochemical metabolomic effects, and biotechnological innovations [42]. Mango varietals, harvesting methods, and postharvest technology have all been studied. The nutritional and phytochemical profile of recycled mango by-products has been studied with the goal of improving the environment [43]. Mango waste patents are becoming increasingly common, with applications especially in the food, pharmaceutical, nutraceutical, and cosmetic industries. [44].

HEALTH BENEFITS

Health benefits of mango are depicted in figure 2.

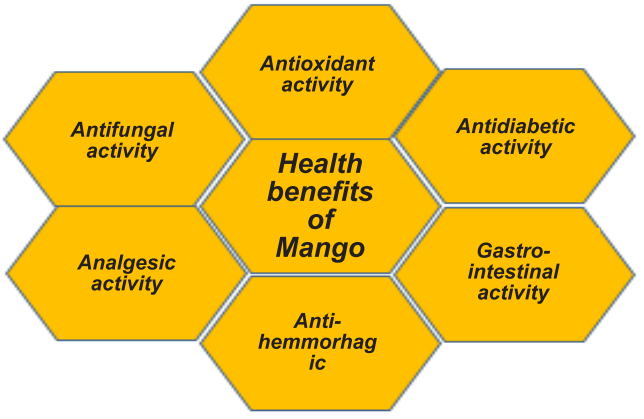

Figure 2: Health Benefits of Mango

Antioxidant Activity

Mangiferin comprises four hydroxyl groups and demonstrates strong free radical scavenging and antioxidant properties [45]. Mangiferin's C-glucosyl linkage and hydroxyl groups contribute to its free radical-scavenging function, with high antioxidant potential in pro-inflammatory situations like infection and diabetes. It reduces hydrogen peroxide-induced lipid peroxidation and guards against damaging hydroxyl radicals and UV rays. Pardo-Andreu *et al.*, reported that mangiferin reduces iron-induced oxygen free radical generation, Fe2+ buildup, and toxicity while also reducing lipid peroxidation in rat liver mitochondria. It also protects osteoblast-like cultured cells against oxidative stress, potentially serving as an osteoporosis treatment [46]. Pokorski *et al.*, reported mangiferin has been shown to protect the liver against carbon tetrachloride-induced damage and arsenic-induced oxidative stress, possibly reducing liver dysfunction [47].

Anti-Diabetic Activity

Several investigations have found that mangiferin shows potential as an anti-diabetic therapy [48]. Mangiferin promoted hypoglycemia by regulating glucose metabolism and insulin resistance. It decreases TNF-α and nitric oxide synthase expression, as well as lowers cholesterol synthesis. Mangiferin therapy has shown significant benefits in diabetic mice, including reduced plasma glucose and lipid levels, increased pancreatic beta cell mass, glucose absorption, and insulin uptake. It also prevents renal fibrosis and lowers collagen IV levels [49]. Mangiferin treatment also lowers IL-1β levels in diabetic rats' serum and kidneys, alleviates chronic renal issues, and normalizes blood urea nitrogen levels. A plant-based diet can regulate high blood sugar levels without frequent medication or insulin, minimizing side effects. Consuming mango leaf extracts and quercetin derivatives has been shown to activate cellular components targeted by anti-diabetic drugs [50].

Gastrointestinal Activity

Mangiferin, a phenolic acid metabolized by colon microflora, has medicinal benefits, including reducing inflammation and gastrointestinal motility [51]. Mangiferin, a laxative agent, has been shown to reduce inflammatory bowel diseases, improve gastrointestinal regularity, and reduce colonic damage. It also offers significant gastroprotection in rodents and mice, and has been found to reduce colonic damage by regulating TNF-α and MMP-9 [52].

Anti-hemorrhagic and Anti-Tetanus Activities

Pithayanukul *et al.*, and Rajasekaran *et al.*, assessed the anti-hemorrhagic properties of mango extract against snake venoms [53,54]. Parvez *et al.*, documented the efficacy of MI leaf extracts against *Clostridium tetani*, a pathogen that is responsible for numerous fatalities worldwide. The anti-clostridium tetani activity of ether and ethanolic leaf extracts was demonstrated with MIC values of 6.25 and 12.5 mg/ml, respectively [55].

Antimicrobial Effects

Mango leaves and stems extracts in ethanol and water at 50 and 25 mg/mL have been shown to have adequate antibacterial activity against the following bacteria: *Pseudomonas aeruginosa*, *Candida albicans*, *Enterococcus faecalis*, *Streptococcus pyogenes*, and *Staphylococcus aureus [56]. Salmonella enterica*, *Listeria monocytogenes*, and *Escherichia coli* were also found to be susceptible to the extract's antibacterial properties [57]. Diso and colleagues investigated the antibacterial properties of Using a concentration of 100µl/ml, Mangifera indica leaf extract was found to be effective against a variety of bacteria, including *Salmonella typhi*, *Pseudomonas fluorescens*, *Shigella flexneri*, *Klebsiella pneumonia*, and *Proteus vulgaris* [58]. Additionally, studies have demonstrated the antibacterial activity of mango extracts against yeast *Candida albicans* and gram-positive and gram-negative bacteria. It is thought that the presence of gallotannin and mangiferin in mango extract is what gives it its antibacterial properties [59]. Moreover, At a dosage of

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6.25 mg/mL, the antifungal properties of methanol, ethanol, and aqueous extracts were observed against *Alternaria alternate* as well [60].

Other Health Benefits

The antipyretic effect of MI stem bark extract on mice was assessed. The extract also decreased the amount of hyperpyrexia brought on by yeast [61]. Amien *et al.*, found that improving kidney function by lowering serum creatinine, urea, and uric acid had a major preventive effect against kidney damage. When rats were treated with 500 and 1000 mg/kg MPS extract, there was a significant increase in the activity of superoxide dismutase (SOD) and reduced glutathione (GSH), and a decrease in total malondialdehyde (MDA) and glutathione-S-transferase (GST) [62]. It has been demonstrated that mangiferin prevents mice's parathyroid hormone-stimulated bone resorption [63]. Batool *et al.*, evaluated the potential anti-diarrheal activities of the methanolic and aqueous extracts of M. indica seeds [64]. Mango kernel aqueous extract's anti-diarrheal qualities were studied by Dam *et al.*, at doses ranging from 0.25 to 0.50 mg/ml [65].

CONCLUSIONS

Mango, a tropical fruit recognized for its sweetness and unusual flavor, is a major source of nutrients worldwide. During their agronomic-to-industrial processing, huge amounts of nonedible wastes (e.g., leaves and barks) and byproducts (e.g., peels, seeds etc.) are produced, resulting in considerable environmental effect as well as economic losses. Primary production, industrial transformation, marketing, and financing in the food industry. Waste is described as innocuous substance that is not meant for human consumption but may be reused, thrown, lost, or biodegraded. The European Union defines waste as any substance or thing that has been or will be discarded. Wastes such as mango residues, which contain minerals and phytochemicals with added value for the nutraceutical industry, are frequently deemed invisible or unsuitable for food makers. As a result, dealing with waste and byproducts is critical for achieving long-term profitability. Its flesh and residues contain beneficial chemicals, that can boost health and lower the risk of chronic diseases. The composition of bioactive substances decreased the disease risk factors.

Authors Contribution

Conceptualization: AJ
Writing-review and editing: AJ, MKN

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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