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**Original Article**

Valorization of Mango (*Mangifera indica*) Peel Waste as a Functional Nutritional Resource with Antioxidant Potential

Muhammad Khalid Saeed^{1*}, Naseem Zahra¹, Hafiza Kainat Anwar¹, Amara Khan², Ijaz Ahmad¹ and Khurram Shahzad¹

¹Department of Food and Biotechnology Research Centre, Pakistan Council of Scientific and Industrial Research, Laboratories Complex, Lahore, Pakistan

²Institute of Food Science and Nutrition, Gomal University, Dera Ismail Khan, Pakistan

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***Corresponding Author:**

Muhammad Khalid Saeed
Department of Food and Biotechnology Research Centre, Pakistan Council of Scientific and Industrial Research, Laboratories Complex, Lahore, Pakistan
rosefbr1@gmail.com

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ABSTRACT

Reducing food waste through full resource utilization has positive effects on the economy, climate, and food security. In order to meet future demand, more food must be produced due to the growing population. The *Mangifera indica* L. (mango) is a widely consumed tropical fruit that is grown and consumed in tropical places worldwide. When mango-based products like juices and purees are made, the peel and kernel are wasted. Mango peel was a good source of nutrients with antioxidant properties. **Objectives:** To assess the nutritional composition and antioxidant activity of mango peel. **Methods:** The nutritional values were determined by using AOAC methods, and the antioxidant activity of water and methanol extract was determined by using the DPPH assay at 517 nm. **Results:** Study outcome depicted that mango peels have protein ($4.30 \pm 0.22\%$), fiber ($4.75 \pm 0.30\%$), ash ($3.52 \pm 0.26\%$), carbohydrates ($78.72 \pm 1.80\%$), and energy Kcal/100g (336 ± 3.45). The results of its antioxidant activity showed that at concentrations of 0.2–1.0 mg/ml, the methanol extract exhibited the highest percentage inhibition (DPPH), ranging from 38.70 ± 1.03 to $81.65 \pm 2.50\%$, while the water extract showed the lowest percentage inhibition (20.10 ± 0.70 – $56.30 \pm 1.95\%$) compared to the standard antioxidant BHA (28.70 ± 0.90 – $65.40 \pm 1.95\%$). There were significant differences found in various extracts and BHA ($p < 0.005$). **Conclusions:** The results of the study showed that mango peel contained nutrients, and its methanolic extracts had significant antioxidant activity, allowing better use of this waste.

INTRODUCTION

Every year, over 1.3 billion tons of food are lost or wasted between the point of production and the point of consumption. In addition, the United Nations estimates that to feed the world's anticipated population by 2050, food demand must rise by 70%. According to the United Nations' 2015 Revision, the current global population of 7.3 billion is predicted to rise to about 9.7 billion by 2050, and it appears to be growing by nearly 30 million people annually. In the European Union, 89 million tons of food waste are

produced annually [1]. The decrease in food waste results in increased economic output and a decrease in greenhouse gas emissions that fuel climate change. The mango (*Mangifera indica* L.) is one of the most frequently grown and consumed tropical fruits in the world due to its high vitamin and antioxidant content. Over 50 million tons of mangoes are produced globally each year. Large countries like Pakistan, India, Bangladesh, China, Mexico, Indonesia, Brazil, Thailand, and the Philippines cultivate



and sell mangoes worldwide [2]. Nevertheless, processing mangoes results in a significant quantity of waste primarily composed of peels and kernels, which, depending on the variety and techniques employed, account for 35–60% of the fruit's weight [3]. In the fruit processing, the peels account for about 15–60% of waste products, which are generally superfluous [4]. The management of this waste highlights a lost opportunity to employ these materials and resolve environmental issues. Mango peels and kernels have been found to contain polyphenols, carotenoids, proteins, essential fatty acids, and dietary fiber that support healthy digestion, blood sugar control, and cholesterol lowering [5]. Antioxidants may reduce the risk of chronic illness by getting rid of free radicals. Mango peel contains antioxidants called beta-carotene and lutein that improve eye health and guard against age-related macular degeneration. It also contains unsaturated fatty acids, which lower low-density lipoprotein cholesterol (LDL) and enhance cardiovascular health, and several cancers are made more likely by chronic inflammation. Mangiferin, present in mango peel, inhibits pro-inflammatory cytokines to decrease inflammation [6]. Gallic and ellagic acids found in mango peels cause cancer cells to undergo apoptosis and reduce the growth of cancer [7].

Although mango processing waste is abundant in Pakistan, especially in the summer season, with a great amount of mango peels, there was limited research to get a complete nutritional profile and antioxidant activities of locally grown mango varieties' peels. Mechanistic understanding of the antioxidant activity observed was limited by the absence of identification and quantification of specific bioactive compounds (such as mangiferin, gallic acid, ellagic acid, and polyphenols) in the sample using advanced analytical techniques. This study aimed to assess the nutritional facts and antioxidant activity of mango peels, which would be wasted during processing.

METHODS

This experimental study was conducted at the Pakistan Council of Scientific and Industrial Research (PCSIR), Laboratories Complex, Lahore, Pakistan, from July 2025 to August 2025. Ten Kg mangoes (chonsa variety) were bought in July 2025 from the local market in Lahore from ten various places. Before analyzing, the samples were collected, cleaned, and washed. The ripe mangoes were peeled before being chopped into small pieces, cleaned with tap water, blanched for 10 minutes at 95°C, drained, and allowed to cool at room temperature. After that, it was dried at 60°C by a hot air oven (local PCSIR Made) for 24 hours [8]. A simple grinder machine (Made in Japan) was used to grind the dried peel into a fine powder, which was

then sieved to produce a final mass of particles with a diameter of 0.6 mm (Figure 1).



Figure 1: Mango Fruit, Its Peel, and Powder

The AOAC methodologies [9] were used to determine the mango peel powder's moisture and ash content, fat, crude protein, and crude fiber. The difference between the total proximate composition and 100% was used to calculate the total soluble carbohydrate as follows: Carbohydrates = 100 - (crude proteins + crude fats + moisture + ash + crude fiber). The energy values (Kcal/100 g) were computed by multiplying the fat and carbohydrate values by nine and four, respectively, and then adding up the results in kilocalories. The antioxidant activity in mango peel powder was measured by using the 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenger [10]. Test tubes were filled with 0.1 ml of different concentrations (0.2–1 mg/ml) of mango peel water and methanol extracts, followed by the addition of 2.9 ml of a 0.1 mM methanolic solution of DPPH and vigorous shaking. For half an hour, the tubes were left at room temperature. As previously mentioned, the control was made without any extract. At 517 nm, the samples' absorbance variations were measured. Antioxidant activity was computed using the formula below, which was represented as the percentage inhibition (% I). DPPH Antioxidant activity (% I) = $\frac{Abs_{blank} - Abs_{sample}}{Abs_{blank}} \times 100$. Three replications of each experiment were used in this investigation, and the findings were shown as \pm standard deviation. The t-test and ANOVA were used to statistically examine the data, which were gathered in triplicate. The graphics were created using SPSS version 21.0 [11].

RESULTS

The yield of mango peels, pulp, and kernel content is shown below, showing that the yield of edible portion/pulp was $70.10 \pm 0.72\%$, the yield of peels was $13.70 \pm 0.42\%$, and the yield of kernels was $16.20 \pm 0.55\%$ (Figure 2).

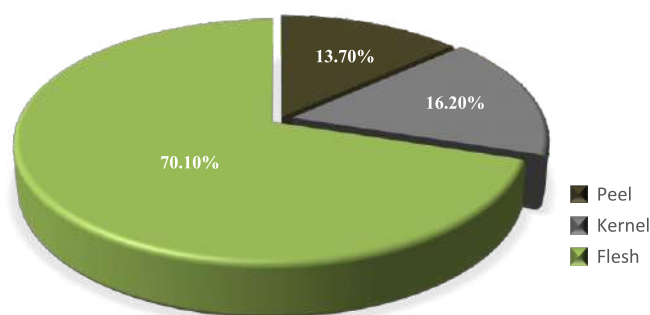


Figure 2: Percentage Yield of Mango Peel, Pulp/Flesh, and Kernel

The mango peel powder included $5.34 \pm 0.37\%$ moisture, $3.37 \pm 0.24\%$ fat, $4.65 \pm 0.02\%$ protein, $4.08 \pm 0.09\%$ ash, 5.51 ± 0.32 fiber, $81.29 \pm 0.78\%$ carbohydrates, and energy 336 ± 3.45 Kcal/100g (Table 1).

Table 1: Nutritional Facts of Mango Peel Powder

Sr. No.	Parameters	Values (g/100g)
1	Moisture	5.34 ± 0.37
2	Ash	3.52 ± 0.26
3	Fat	3.37 ± 0.24
4	Fiber	4.75 ± 0.30
5	Protein	4.30 ± 0.22
6	Carbohydrate	78.72 ± 1.80
7	Energy (Kcal/100g)	336 ± 3.45

Data were represented \pm standard deviation

The results revealed that the methanol extracts had a substantial antioxidant capacity ranging from 38.70 ± 1.03 to $81.65 \pm 2.50\%$. Standard synthetic antioxidant BHA (28.70 ± 0.90 to $65.40 \pm 1.95\%$) and water extract (20.10 ± 0.70 – $56.30 \pm 1.70\%$) at the same concentration of 0.2–1.0 mg/ml. There were significant differences found in various extracts and BHA ($p < 0.005$). (At concentration 0.2–1.0 mg/ml) (Figure 3).

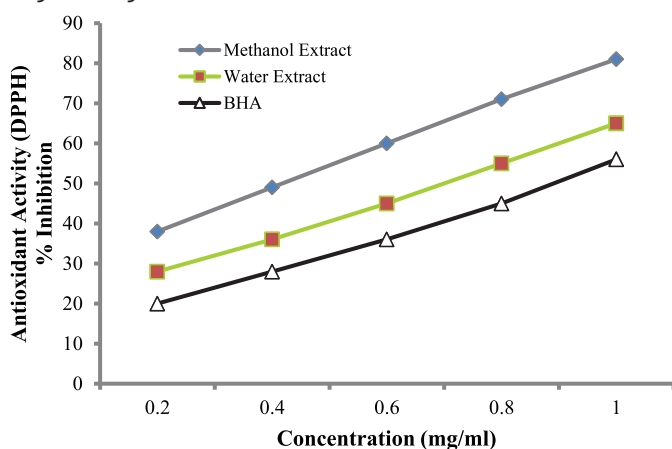


Figure 3: Antioxidant Activity (DPPH) % Inhibition of Mango Peel Powder

DISCUSSION

An intriguing line of inquiry is the potential to transform food industry waste byproducts into useful food additives and natural antioxidants. The yield of mango peels, pulp, and kernel content, and the nutritional and antioxidant qualities of dried mango peel powder were all examined in this study. According to the literature, the edible pulp ranged 62.3–70.2% of the fresh fruit, whilst the peel makes up 13.6–21.4% and kernel 15.2–20.5% [12, 13]. The current study results were within above mention results. Fruits are an essential component of our diet and are frequently consumed by most people worldwide either at random or as a "custom of dessert" following meals. These fruits have a highly important nutritional makeup, although the nutritional makeup of different fruit kinds varies significantly as well [14]. Mango fruits are an important source of vitamins, phytochemicals, and minerals, according to a wealth of research. Mangoes also provide vital elements like calories, proteins, lipids, carbohydrates, dietary fiber, and phenolic compounds. Similar findings were reported in another study, which showed the values of protein, fat, and ash in mango peel powder, which ranged from 1.4–6.9%, 1.6–4.4%, and 1.1–4.2%, respectively [15]. According to earlier findings, the peel has substantial levels of crude fiber (8%), pectin (13%), and carbohydrates (80%) together with respectable amounts of proteins (4%) and lipids (2%) [16]. The antioxidant activity of mango peel powder was determined by DPPH assay, also called the scavenging assay, which is an antioxidant technique that relies on hydrogen atom donation to reduce DPPH radicals. As a result, the hue changes from violet or purple to pale yellow, signifying the creation of stable molecules [17, 18]. Antioxidants found in mango peel have pharmacological effects that improve health, including reducing oxidative stress, which can lead to cancer, diabetes, and cardiovascular disease [19]. Mango peel polyphenols reduce oxidative stress in vitro, indicating that frequent consumption may improve health [20]. The antioxidant activity in the methanol extract is higher than that of the water extract because methanol is the best solvent for the extraction of antioxidant compounds like polyphenols [21]. The mangiferin, the primary phenolic compound of mangos, which is a member of the xanthone class, is present in higher amounts in the methanol extract than in the water extract [22]. The potential of the bioactive compounds found in mango peel to lower the risk of a number of illnesses, including cancer, Parkinson's disease, Alzheimer's disease, and cataracts, has been well-documented. One of the main ingredients in mango peels, mangiferin, has been particularly linked to a decreased risk of cancer. Furthermore, functional substances with antibacterial, anti-diabetic, anti-inflammatory, and anti-

carcinogenic qualities include protocatechuic acids and β -carotene [23]. Gallate-type compounds, such as penta-O-galloyl-glucoside, have been shown in pharmaceutical research to exhibit a variety of bioactivities, such as anti-tumor, antioxidant, anti-cardiovascular, and hepatoprotective properties [24, 25]. Mango peel, which contains natural protein, fiber, and antioxidants, can be utilized to separate active ingredients and incorporate them into a variety of processed foods, such as baked goods, breakfast cereals, pasta, snacks, drinks, and energy bars, with both financial and health advantages [26]. Mango peel's sugars can be used to produce bio-ethanol, which will help build renewable energy sources, and it can be used in animal feed. In keeping with the ideas of the circular economy, these applications boost the value of mango byproducts across industries and encourage sustainability.

Despite these promising outcomes, the study was limited by a relatively small sample size and the absence of in vivo investigations due to resource constraints. Therefore, future research should focus on optimizing extraction methodologies, evaluating bioavailability and safety through in vivo studies, and exploring the incorporation of mango peel into innovative functional food products with enhanced health benefits.

CONCLUSIONS

The findings of this study demonstrate that mango peel is a valuable source of bioactive and nutritional compounds, including proteins, dietary fibre, and phenolic constituents with significant antioxidant potential. These results highlight the promising role of mango peel as a sustainable raw material for the development of value-added functional foods and nutraceutical applications. Utilisation of mango-processing byproducts not only reduces agro-industrial waste but also contributes to environmental sustainability and resource recovery within the food industry. Furthermore, the study emphasises the importance of advancing research on efficient compound extraction, recovery technologies, and targeted industrial applications to ensure commercial feasibility and long-term product sustainability.

Authors' Contribution

Conceptualization: MKS

Methodology: MKS

Formal analysis: NZ, HKA, AK

Writing and Drafting: MKS, IA, KS

Review and Editing: MKS, NZ, NKA, AK, IA, KS

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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