



**ANTIOXIDANT ACTIVITY, NUTRIENT ANALYSIS, AND PHYTOCHEMICAL STUDY
IN RIPE AND UNRIPE MANGO, LEMON, AND ORANGE PEELS.**

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Article Received on 05/07/2024

Article Revised on 26/07/2024

Article Accepted on 16/08/2024

ABSTRACT

Fruit peels are the outermost protective layers of fruits that have practical as well as decorative uses. Depending on the fruit, they differ greatly in thickness, color, and texture. Fruit peels have many applications if these variables are understood, and they are becoming an increasingly valuable by-product in the food and pharmaceutical industries. To study investigates the antioxidant, nutritional, and phytochemical profiles of ripe and unripe peels from mangoes (*Mangifera indica*), lemons (*Citrus limon*), and oranges (*Citrus sinensis*) to explore their potential health benefits and industrial applications. Through DPPH and FRAP assays, nutrient analysis, and phytochemical quantification, we evaluated the antioxidant capacity, nutrient composition, and levels of phenolic compounds and flavonoids in fruit peels. Results revealed that unripe mango peels exhibit superior antioxidant activity and higher fiber content, making them suitable for dietary supplements. Ripe lemon and orange peels showed enhanced antioxidant with ripe orange peels being particularly rich in calcium and iron. This study emphasizes the significance of fruit peels as valuable, resource-efficient sources of health benefits and points out their potential applications in functional foods and natural preservatives.

KEYWORDS: Fruit peels, antioxidant activity, phytochemical profiles, mango, lemon, orange, nutritional analysis, functional food.

INTRODUCTION

Fruits are an essential component of human nutrition and gastronomy; they are valued for both their meat and, more and more, for their peels, which are known to contain a wealth of bioactive components. Fruit peels were once thought to be waste, but new scientific research has shown that they have important health advantages and industrial potential. The peels of mangoes (*Mangifera indica*), lemons (*Citrus limon*), and oranges (*Citrus sinensis*) are examined in this research, with an emphasis on their phytochemical profiles, antioxidant activity, and antibacterial qualities. Fruit peels are the fruit's outer, protective skin and are a rich source of nutrients and bioactive substances. Peels were once thrown away, but today they are valued for their nutritional, antibacterial, and antioxidant qualities. Their application has grown to include things like natural preservatives, cosmetics, and functional foods. (Liaudanskas et al., 2020). Tropical fruits that are prized for both their taste and nutritional value are mangoes. Polyphenols, flavonoids, and carotenoids are only a few

of the beneficial substances found in the peel, which is frequently removed. These substances support the antioxidant and antibacterial properties of the peel. (Khan et al., 2018).

Ripe mango peels include higher concentrations of polyphenols like mangiferin and carotenoids like beta-carotene, they have a richer color and heightened taste. According to Wu et al (2021), the high mangiferin concentration of ripe mango peels contributes to their significant antioxidant capacity. This antioxidant function helps prevent disorders linked to oxidative damage. On the other hand, unripe mango peels include varying amounts of phytochemicals, despite being less sweet and more astringent. Their abundance of tannins has been demonstrated to have potent antibacterial properties (Akinmoladun et al., 2016). The compositional variations between ripe and unripe mango peels point to a variety of possible uses, including as natural antibacterial agents and dietary supplements.

Lemons are well-known for their acidic flavor and high vitamin C content. According to Sharma et al. (2019), the peels of lemons are especially rich in flavonoids and essential oils like hesperidin and eriocitrin. These substances support their antibacterial and antioxidant qualities.

The strong scent and higher concentration of essential oils, such as limonene and citral, that characterize ripe lemon peels set them apart. The peels' strong antioxidant and antibacterial properties are caused by these substances (Lee et al., 2021). Ripe peels have more flavonoid and vitamin C content, which increases their nutritional worth and health advantages. Even though they are less fragrant, unripe lemon peels differ in the amounts of some acids and phytochemicals. When compared to their ripe counterparts, these peels have been shown to contain variable levels of antioxidant and antibacterial activity (Choudhury et al., 2022). Applications in industry and medicine can be made of their distinct chemical character.

Oranges are well known for their high vitamin C content and pleasant flavor. The peels are packed with dietary fiber, essential oils, and a wide variety of flavonoids (Kumar et al., 2021). These elements, which also have antibacterial and antioxidant qualities, add to their health advantages. Due to their high concentration of essential oils like limonene and flavonoids like hesperidin, ripe orange peels are recognized for their vibrant color and potent scent. According to Ferreira et al. (2018), these substances have increased antioxidant and antibacterial properties. Ripe orange peels provide more nutritional value for food and health uses because of their increased fiber and vitamin C content. Ripe orange peels are known for their vivid color and strong aroma because of their high content of flavonoids like hesperidin and essential oils like limonene. Ferreira et al. (2018) claim that these compounds had enhanced antibacterial and antioxidant qualities. Because they include more fiber and vitamin C, ripe orange peels have higher nutritional value for food and health purposes.

Mango peels, especially those from ripe mangoes, have antibacterial and antioxidant qualities that make them good for use in nutritional supplements and functional meals. Furthermore, the high fiber content and bioactive substances present prospects for the development of natural preservatives and products that enhance health. (Kumar and others, 2019).

Because of their flavor and essential oils, lemon peels are used in many industries, such as food, beverage, and cosmetics. Ripe lemon peels have a high antioxidant content that makes them useful for cosmetic products and health supplements. Additionally, unripe peels may be used in functional foods and natural preservative formulations (Ali et al., 2020). Orange peels are utilized in a variety of items, including flavorings, natural medicines, and cosmetics. They are a good fit for

functional food ingredients and health supplements due to their high phytochemical profile. According to Hossain et al. (2020), the unique characteristics of ripe and unripe peels provide a wide range of applications in various industries. Hence the study framed to investigate the antioxidant, nutritional, and phytochemical profiles of ripe and unripe peels from mangoes (*Mangifera indica*), lemons (*Citrus limon*), and oranges (*Citrus sinensis*) to explore their potential health benefits and industrial applications.

MATERIALS AND METHODS

Collection of Mango, Lemon and Orange Peels

Mangoes (*Mangifera indica*) were gathered at a Hyderabad, Telangana local market, both ripe and unripe. Unripe mangoes are firm and green, while ripe mangoes are full-colored and have a delicious aroma. Lemons (*Citrus limon*) green, firm, completely ripe lemons were collected together with unripe lemons that are firm and bright yellow. Oranges (*Citrus sinensis*) ripe oranges that are firm and green to the touch, as well as unripe oranges that are orange, were collected.



Fig. 1: Unripe Mango Peel.



Fig. 2: Ripe Mango Peel.



Fig. 3: Unripe Lemon Peel.



Fig. 4: Ripe Lemon Peel.



Fig. 5: Unripe Orange Peel.



Fig. 6: Ripe orange Peel.

Extraction of Sample

50–100 mL of methanol are combined with 5–10 grams of dried peel in a glass jar. After letting the mixture soak for 24 to 48 hours at room temperature, it is periodically stirred. To get a clear liquid extract, the mixture is filtered

using either fine mesh or Whatman No. 1 filter paper after soaking. Using a rotary evaporator, concentrate the filtrate to eliminate methanol while operating at a lower pressure. A concentrated extract is produced in this stage.

Determination of Antioxidant Activity - DPPH

Method

Grind the peels into a fine powder after drying. Using 10 milliliters of methanol, extract 1 gram of the powdered material and filter. In methanol, combine 1 mL of extract with 3 mL of a 0.1 mM DPPH solution. Allow the mixture to sit at room temperature in the dark for half an hour. Using a spectrophotometer, the absorbance is determined at 517 nm. The antioxidant activity is determined by calculating the percentage of DPPH radical scavenging (S. J. S. Lee, M. J. Lee, 2011).

FRAP METHOD

Grind the peels into a fine powder after drying. Using 10 milliliters of methanol, extract 1 gram of the powdered material and filter. Combine 3 mL of FRAP reagent (consisting of 2.5 mL of 10 mM 2,4,6-tripyridyl-s-triazine in 40 mM HCl and 2.5 mL of 20 mM FeCl₃) with 100 µL of extract. Incubate at 37°C for 30 minutes. Assess the absorbance at 593 nanometers. (S. J. S. Lee, M. J. Lee, 2011) A ferrous sulfate standard curve can be used to calculate antioxidant activity.

Nutrient Analysis

Proximate analysis of fruits peel was done by standard methods. Moisture content was determined by drying the sample in an oven at 105 °C until constant weight was reached. The ash content was determined by burning the sample in a muffle furnace at 550 °C until all the organic matter was burned. Crude protein content was determined using the Kjeldahl method. Crude fat content was determined using the Soxhlet extraction method with petroleum ether as solvent. Crude fiber content was

determined using the acid-alkaline digestion method (Singh et al., 2012).

Mineral Analysis

Mineral Analysis of Ripe and Unripe Mango, Lemon, and Orange Peels was done by standard methods. Calcium content was assessed through Atomic Absorption Spectrophotometer method or other suitable technique. Iron content was assessed by Soxhlet method with petroleum ether as solvent. (J. M. Patel, R. G. Yadav 2008).

Determination of Total Phenolic content

Total phenols were measured when the peels are dried off and powdered. Using 10 milliliters of methanol, extract one gram of powder. Combine 2.5 mL of Folin-Ciocalteu reagent with 0.5 mL of extract. Add 2 milliliters of 7.5% sodium carbonate. Allow to react in the dark for half an hour (S. J. S. Lee, M. J. Lee, 2011) Measure absorbance with a spectrophotometer at 765 nm measured in milligrams of gallic acid equivalents (GAE) per gram.

2.7. Determination of Total Flavonoid content

Dry off and powder the peels. Using 10 milliliters of methanol, extract one gram of powder. Blend 1 milliliter of the extract with 1 milliliter of 2% aluminum chloride solution and 1 milliliter of 1 M sodium acetate. Allow to react at room temperature for half an hour (S. J. S. Lee, M. J. Lee, 2011) Measure absorbance with a spectrophotometer at 430 nm. Report findings in milligrams of quercetin equivalents per gram.

RESULTS AND DISCUSSION

Nutrient analysis

The nutrient analysis of ripe and unripe peels from mangoes, lemons, and oranges, presented in Table 1, reveals significant variations in their composition based on ripeness and fruit type.

Table 1: Nutrient Analysis of Ripe and Unripe Mango, Lemon, and Orange Peels per dry weight.

Parameters	ripe mango peel	unripe mango peel	ripe lemon peel	unripe lemon peel	ripe orange peel	unripe orange peel	Units
Carbohydrate	45.15	33.20	37.42	32.35	47.50	37.65	g/100g
Fat	1.75	1.6	1.65	1.5	1.3	1.4	g/100g
Protein	2.5	1.80	1.60	1.20	1.5	1.5	g/100g
Moisture	10.20	16.45	26.30	38.45	15.35	23.70	g/100g
Ash	5.60	7.40	9.4	10.20	7.50	9.20	g/100g
Fiber	30.75	35.60	18.30	28.90	24.60	37.45	g/100g
Pectin content	8.52	22.67	15.25	20.75	24.60	30.75	g/100g

Ripe mango peels exhibited the highest carbohydrate content at 45.15 g/100g, while unripe lemon peels had the lowest at 32.35 g/100g. Ripe orange peels also showed a high carbohydrate level (47.50 g/100g), indicating their potential as a valuable energy source. Carbohydrates in fruit peels are crucial as they contribute to the energy intake and could be utilized in functional food applications.

The fat content in all peels was relatively low, with ripe mango peels containing the highest amount (1.75 g/100g) and ripe orange peels the lowest (1.30 g/100g). The minimal fat content across the peels suggests their limited use in fat-related dietary applications but highlights their suitability for low-fat formulations.

Ripe mango peels had the highest protein content (2.50 g/100g), whereas unripe lemon peels had the lowest (1.20 g/100g). Protein is essential for various physiological functions, and the higher protein content in ripe mango peels could be advantageous for developing protein-enriched dietary supplements.

Ripe lemon peels had the highest moisture content (26.30 g/100g), while ripe mango peels had the lowest (10.20 g/100g). The high moisture content in unripe peels (particularly lemon) could affect their shelf-life and processing characteristics, making ripe peels preferable for long-term storage and use. The ash content, which reflects the mineral content, was highest in unripe lemon peels (10.20 g/100g) and lowest in ripe mango peels (5.60 g/100g). The higher ash content in lemon peels suggests a greater mineral density, which could enhance their nutritional value. Unripe mango peels had the highest fiber content (35.60 g/100g), while ripe lemon peels had the lowest (18.30 g/100g). High fiber content in unripe mango and orange peels suggests their potential use in dietary fiber supplements, aiding in digestion and

promoting gut health. Unripe orange peels had the highest pectin content (30.75 g/100g), followed by unripe mango peels (22.67 g/100g). Pectin is valuable for its gelling properties and potential use in food industry applications, such as natural gelling agents or stabilizers.

Ripe mango and orange peels show high carbohydrate levels, making them suitable for energy-dense applications. In contrast, unripe peels generally have higher fiber and pectin content, indicating their potential use in high-fiber diets and as natural gelling agents, respectively. The high fiber and pectin content in unripe peels, combined with the high carbohydrate content in ripe peels, offer diverse applications in health and food industries.

Mineral analysis

The mineral analysis of calcium and iron in ripe and unripe peels of mangoes, lemons, and oranges reveals distinct differences based on fruit type and ripeness, as detailed in Table 2.

Table 2: Mineral Analysis of Ripe and Unripe Mango, Lemon, and Orange Peels per dry weight.

Parameters	ripe mango peel	unripe mango peel	ripe lemon peel	unripe lemon peel	ripe orange peel	unripe orange peel	Units
Calcium	225	280	270	345	420	545	mg/100g
Iron	3.15	4.80	2.35	4.0	2.5	4.85	mg/100g

Ripe mango peels contained 225 mg of calcium per 100 grams of dry weight, while unripe mango peels had a higher calcium content of 280 mg/100g. Ripe lemon peels exhibited 270 mg of calcium per 100 grams, and unripe lemon peels had the highest calcium content among lemons, at 345 mg/100g. Ripe orange peels contained 420 mg of calcium per 100 grams, with unripe orange peels showing the highest calcium content overall at 545 mg/100g. This suggests that unripe orange peels are exceptionally rich in calcium, making them a valuable source of this mineral. Unripe lemon peels also provide a significant amount of calcium. In contrast, ripe mango peels have the lowest calcium content among the peels studied, although unripe mango peels offer a higher amount, indicating that calcium concentration tends to increase as mango peels mature.

The analysis of iron content reveals that unripe peels generally have higher levels compared to ripe peels. Specifically, unripe orange peels contained 4.85 mg of iron per 100 grams, the highest among all samples, while unripe mango peels had 4.80 mg/100g. In comparison, ripe mango peels had 3.15 mg of iron, and ripe lemon peels had the lowest iron content at 2.35 mg/100g. These results suggest that iron concentration in peels increases before the fruit ripens, emphasizing the higher iron content in unripe peels. The reduction in iron levels observed in ripe lemon and orange peels compared to

their unripe counterparts indicates a decline in iron concentration as the fruit matures.

Total phenolic and flavonoid content in fruit peels

The total phenolic and flavonoid content in ripe and unripe peels of mangoes, lemons, and oranges (Table 3). Total Phenolic Content analysis revealed that ripe mango peels contained 2.60 mg GAE/g (gallic acid equivalents), whereas unripe mango peels had a higher phenolic content of 4.50 mg GAE/g. Ripe lemon peels showed a total phenolic content of 3.20 mg GAE/g, which increased to 7.54 mg GAE/g in unripe lemon peels. Ripe orange peels had 6.35 mg GAE/g, while unripe orange peels exhibited the highest total phenolic content at 9.42 mg GAE/g. These results indicate that unripe peels generally contain more phenolic compounds compared to their ripe counterparts. The increase in phenolic content with ripeness in mango and lemon peels, and particularly in unripe orange peels, highlights the potential of these peels as rich sources of antioxidant compounds.

Table 3: The total phenolic and flavonoid content of Ripe and Unripe Mango, Lemon, and Orange Peels per dry weight.

Parameters	ripe mango peel	unripe mango peel	ripe lemon peel	unripe lemon peel	ripe orange peel	unripe orange peel	Units
Total Phenolic content	2.60	4.50	3.20	7.54	6.35	9.42	mg GAE/g
Total Flavonoid content	18.85	32.50	16.50	36.25	27.42	45.40	mg QE/g

The total flavonoid content was 18.85 mg QE/g (quercetin equivalents) in ripe mango peels and increased significantly to 32.50 mg QE/g in unripe mango peels. Ripe lemon peels had 16.50 mg QE/g, which rose to 36.25 mg QE/g in unripe lemon peels. Ripe orange peels contained 27.42 mg QE/g, and unripe orange peels had the highest flavonoid content at 45.40 mg QE/g. The data demonstrates that unripe peels possess a higher concentration of flavonoids compared to ripe peels.

Unripe orange peels had the highest levels of both total phenolic (9.42 mg GAE/g) and total flavonoid content (45.40 mg QE/g), indicating their superior antioxidant potential. Similarly, unripe lemon and mango peels also showed elevated levels of these phytochemicals compared to their ripe fruit peel. The higher phenolic and

flavonoid contents in unripe peels suggest that these peels may offer enhanced antioxidant benefits and potentially greater health-promoting properties. The increased antioxidant capacity in unripe peels could be attributed to the higher concentration of bioactive compounds, which are known for their protective effects against oxidative stress.

Total Antioxidant activity of Ripe and Unripe Mango, Lemon, and Orange Peels

The antioxidant activity of ripe and unripe peels from mangoes, lemons, and oranges, measured using DPPH (IC₅₀ values in ppm) and FRAP (mmol Fe²⁺/g) assays shown in (Table 4).

Table 4: Total Antioxidant activity of Ripe and Unripe Mango, Lemon, and Orange Peels per dry weight.

Parameters	ripe mango peel	unripe mango peel	ripe lemon peel	unripe lemon peel	ripe orange peel	unripe orange peel	Units
DPPH	280	166	375	245	325	293	IC ₅₀ ppm
FRAP	1.50	2.70	0.75	2.25	0.84	1.45	mmol Fe ²⁺ /g

The DPPH assay results indicate that ripe mango peels have an IC₅₀ value of 280 ppm, whereas unripe mango peels exhibit a significantly lower IC₅₀ value of 166 ppm, indicating greater antioxidant activity. For lemons, ripe peels show an IC₅₀ value of 375 ppm, which decreases to 245 ppm in unripe lemon peels. Ripe orange peels have an IC₅₀ value of 325 ppm, while unripe orange peels have a lower IC₅₀ value of 293 ppm. These results suggest that unripe peels generally have higher antioxidant activity compared to their ripe peels.

The FRAP assay results show that ripe mango peels have a ferric reducing antioxidant power of 1.50 mmol Fe²⁺/g, which increases to 2.70 mmol Fe²⁺/g in unripe mango peels. Ripe lemon peels have a FRAP value of 0.75 mmol Fe²⁺/g, compared to 2.25 mmol Fe²⁺/g in unripe lemon peels. Ripe orange peels show a FRAP value of 0.84 mmol Fe²⁺/g, which increases to 1.45 mmol Fe²⁺/g in unripe orange peels. These findings further indicate that unripe peels exhibit higher antioxidant capacity compared to ripe peels.

Unripe fruit peels generally exhibit higher antioxidant capacities than their ripe counterparts. The lower IC₅₀ values observed for unripe peels in the DPPH assay indicate a greater effectiveness in scavenging free

radicals, suggesting enhanced antioxidant properties. Similarly, the higher FRAP values in unripe peels reflect a greater ability to reduce ferric ions, reinforcing their superior antioxidant activity. The observed increase in antioxidant activity in unripe peels could be attributed to the higher concentrations of phenolic compounds and flavonoids in these peels, which are known to contribute to antioxidant defense mechanisms. These findings highlight the potential of unripe fruit peels as valuable sources of natural antioxidants, which could be utilized in the development of functional foods and nutraceuticals aimed at enhancing oxidative stress protection.

CONCLUSION

This study reveals that unripe peels of mangoes, lemons, and oranges generally exhibit superior nutritional and antioxidant profiles compared to their ripe counterparts. Unripe peels demonstrate higher contents of essential minerals such as calcium and iron, along with increased levels of phenolic compounds and flavonoids, which contribute to their enhanced antioxidant activity. The higher concentrations of fiber and pectin in unripe peels further suggest their potential applications in dietary fiber supplements and as natural gelling agents. These results highlight the significant nutritional and functional benefits of unripe fruit peels, emphasizing their potential

in creating health-enhancing products and functional foods.

Agricultural and Food Chemistry, 2021; 69.23: 6596-6605.

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