Journal of Applied Horticulture, 27(2): 318-322, 2025
https://doi.org/10.37855/jah.2025.v27i02.59
Journal of Applied Horticulture
ISSN: 0972-1045

Exploring nutritional composition and antioxidant potential of papaya peels in Bangladesh

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Abstract

This study examined the nutritional composition and the antioxidant properties of unripe papaya (*Carica papaya* L. var BARI Papaya-1) peel powder which could be an ideal functional food source to be incorporated into food products in the future. From the analysis, it showed that the peel powder is rich in nutrients containing protein (10.51%), crude fiber (15.58%), moisture (9.41%), ash (6.33%), carbohydrate (57.07%) and energy (280.24 kcal/100 g). It further revealed substantial content of bioactive vitamins with antioxidant activity, such as vitamin C (60.6 mg/100 g), β-carotene (2952.08 µg/100 g), and vitamin A (246.01 RE/100 g). The results indicated that the peel powder had total phenolic content (1216.75 mg GAE/100 g DW), total flavonoid content (158 mg QE/100 g DW), and excellent total antioxidant activity (161.75 mg/100 g DW). The free radical scavenging ability was remarkably higher in peel powder in particular, with the highest DPPH radical inhibition of 74.41% obtained from the 80% methanolic extract of peel powder. Thus, these results indicate that the unripe peel powder of papaya can be used as a potential source of nutrients and antioxidants for health-promoting food and nutraceutical applications.

Key words: Antioxidants, papaya, peel, nutritional profile, polyphenols

Introduction

Papaya (*Carica papaya* L.) is a member of the Caricaceae family, which is widely grown for its high nutritional content (Ali *et al.*, 2012). In Bangladesh, farmers plant BARI Papaya-1, also referred to as Shahi papaya, which is a superior variety (He *et al.*, 2017). Strong antioxidants, including vitamins C, A, and E, as well as the minerals potassium and magnesium, the B vitamin pantothenic acid, folate, and fiber, are all abundant in papayas. Furthermore, it has the digestive enzyme papaintha, which is beneficial in treating sports injuries, allergies, and trauma-related conditions (Bhowmik, 2013). Antioxidants are of paramount importance in protecting biological systems from the detrimental effects of oxidative stress, which is connected to the development of several illnesses as well as ageing.

Numerous research works have documented the diverse pharmacological characteristics of *C. papaya*. For example, in China, stomachaches, bacterial infections, and inflammations are treated with *C. papaya* leaves, fruits, and seeds (Zhang *et al.*, 2022). The *C. papaya* plant has a variety of properties, including anti-inflammatory, anti-tumour, wound-healing, antimicrobial, antifungal, anti-inflammatory, anti-fertility, histaminergic, antiamoebic, antihypertensive, hepato-protective, anti-malarial, hypoglycemic, immune-modulatory, anti-ulcers, and anti-sickling effects (Faijan and Maheshwari, 2023). While the unripe green fruit can be used either fresh or cooked, it is typically consumed cooked in stews, salads, and curries. Papaya peel is used in several impoverished tropical nations as one of the main ingredients in meals (Martial-Didier *et al.*, 2017).

Nowadays, the consumption of peels obtained from fruits as a natural antioxidant source and formulation of peel-based food products is a growing concern due to their nutritional as well as phytochemical properties. Owing to papaya's widespread use as a vegetable and fruit as well as its medicinal and pharmacological qualities, mass manufacturing makes it necessary to analyze the unripe peel to look into its bioactive substances, functional qualities, *etc.* Therefore, the purpose of this study was to examine the proximate composition (moisture, ash, protein, fat, carbohydrate, fiber, energy), vitamins (vitamin A, vitamin C), and antioxidant properties (total phenolic content, total flavonoid content, total antioxidant capacity, and antioxidant activity) of unripe BARI Papaya-1 peel powder. The results of this study may have significant implications for both the food industry and public health, highlighting the importance of harnessing the nutritional and antioxidant potential of fruit and vegetable peels to address pressing global challenges. As far as we are aware, this is the first research done specifically in Bangladesh to evaluate the antioxidant properties of unripe papaya peel and would fill gaps in knowledge about the proximate composition, vitamin content, and antioxidant properties of unripe papaya peel, thereby encouraging its utilization as a functional ingredient or a pharmacological resource.

Materials and methods

The reagents that were used in this study, like hexane, ethyl acetate, chloroform, ethanol, petroleum ether, anhydrous

Na_2CO_3 crystals, sulfuric acid, sodium biphosphate, ammonium molybdate, sodium nitrite, aluminium chloride, sodium hydroxide, ascorbic acid, quercetin, 2,6-dichloroindophenol, and methanol, were acquired from Merck Co. (Darmstadt, Germany). 2,2-Diphenyl-1-pikryl-hydrazyl (DPPH), quercetin, gallic acid, and the Folin-Ciocalteu reagent, phosphomolybdate were obtained from Sigma-Aldrich (St. Louis, MO, USA). The SPECORD 250 Spectrophotometer (Germany) was used for colorimetric analysis.

Sample collection and preparation: Unripe BARI Papaya-1 fruits were collected from Bangladesh Agricultural Research Institute (BARI). After washing the papayas properly with water, peeling was done to obtain fresh peels. The peels were then treated to blanching and dried at 60 degrees Celsius in an oven (Model: DSO-300D, Taiwan). The dehydrated peels were crushed well in a blender (Brand: Philips, Model: Simply Silent, 600W) to achieve fine powder. In a shaker, oven-dried peel powder (0.5-2 g) was mixed with 20-25 mL methanol (80 %) for 24 h at normal room temperature. Next, the powder was placed under centrifugation (Kubota, Model:5100, Japan) for 15 to 20 minutes at a rate of 3000 revolutions per minute (rpm). Filtration of the extract was done through the filter paper (Whatman No. 1). Using a rotary evaporator (Model: RE100-Pro, 1300 W, USA) at 45°C and decreased pressure, the extracted sample was concentrated by evaporating the solvent and stored in refrigerated at -4˚C for further analysis (Sultana *et al.*, 2009).

Proximate analysis: To determine the levels of moisture, crude fiber, and total ash, AOAC (2000) methods were followed. The crude protein content was estimated by multiplying the nitrogen concentration by a factor of 6.25. The fat was analyzed, and the crude lipid was removed (AOAC, 2000). The determination of carbohydrate content involved subtracting moisture, ash, crude proteins, crude lipids, and crude fiber percentages out of a total of 100 (Sumon *et al.*, 2018). The method described by Buchholz *et al.* was used to determine the energy content of the papaya peel powder (Buchholz and Schoeller 2004).

Vitamin concentrations: The volumetric approach was used to assess the ascorbic acid concentration of peel extracts (Rekha *et al.*, 2012), and the spectrophotometric method was followed to determine the measurement of β-carotene (Grootaert *et al.*, 2021).

Total phenolic content (TPC): The Folin-Ciocalteu technique with modest modifications was used to assess the TPC content of all the extracts. The FCR is employed to decrease samples containing polyphenols, forming a complex with a blue colouration. A calibration curve based on gallic acid was used to determine the phenolic content of the extracted sample. 2.5 mL of ten-fold-diluted FCR and 2 mL (75 g L^{-1}) sodium carbonate were combined with 0.5 mL aliquots of 100, 200, 400, 600, and 800 µg mL^{-1} methanolic gallic acid solutions to create a calibration curve. The mixture was left to stand for 30 minutes at ambient temperature before determining the absorbance at 760 nm by spectrophotometry. Each experiment was carried out three times. The quantification of total phenolic content was conducted by expressing it as gallic acid equivalent (GAE) in milligrams per 100 grams of extract (Islam *et al.*, 2013).

Total flavonoid content (TFC): TFC was determined with a small modification of a widely used aluminium chloride colorimetric test, with Quercetin serving as the standard. 100 microliters of extract were combined with 4 milliliters of distilled water at the outset. Finally, 5 % sodium nitrite (in 0.3 mL) was added. A 10 % aluminum chloride solution was added after waiting 5 minutes. Two mL of 1 M sodium hydroxide were added after a six-minute pause. After properly mixing the concoction, it was diluted with 3.3 mL of distilled water. In comparison to a blank, absorbance was measured at 510 nm. The total flavonoid content was reported as the quercetin equivalent in milligrams per one hundred grams of extract (mg 100 g^{-1}) (Fattahi *et al.*, 2014).

Total antioxidant capacity (TAC): A modified phosphomolybdate technique was utilized to determine TAC (King *et al.*, 2013) using ascorbic acid as the standard. An acidic environment leads to the formation of a green phosphate/Mo (V) complex when the sample reduces Mo (VI) to Mo (V). To produce concentrations between 0.05 and 1 mg mL^{-1}, a stock solution of 1 mg mL^{-1} (test samples) was made. An aliquot of 0.1 mL or the required amount of sample solution was mixed with 1 mL of the reagent solution (0.6 M sulfuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate). For 90 minutes, the sample tubes were sealed and submerged in a water bath that was heated to 95˚C. The absorbance was measured by comparing the sample to a blank reading taken with a UV-visible spectrophotometer at 695 nm once the sample had reached room temperature.

DPPH radical scavenging assay: The stable radical 1,1-diphenyl-2picrylhydrazyl (DPPH) was used to test the radical-scavenging or hydrogen-donating capabilities of extracts using ascorbic acid as the standard with modest modification (Chu *et al.*, 2000). 2 mL of each extract and standard at varied doses (100, 50, 25, 12.5, 6.25, and 0.812 µg mL^{-1}) were added to 3 mL of newly made DPPH solution (0.004 %) in methanol (99 %). After 30 minutes of reaction time, absorbance at 517 nm was measured with a spectrophotometer (SPECORD 250). Each experiment was conducted three times independently. The extract's scavenging efficacy was assessed by the degree of DPPH decolorization, which changed from purple to yellow. Using the following formula, the % inhibition was determined:

$$\text{DPPH Inhibition (\%)} = [(A_c - A_s) / A_c] \times 100$$

A_c represents the control absorbance, while A_s denotes the sample/standard absorbance. Following the plotting of the percentage inhibition data against log concentration on a graph, linear regression analysis was used to determine the IC_{50} (half-maximum inhibitory concentration).

Statistical analysis: All of the tests were performed in triplicate (n = 3), and the findings are shown as means and standard deviations (Mean ± SD). To assess the statistical significance of the differences between means, a one-way analysis of variance (ANOVA) followed by Duncan's test was employed. All of these analyses were conducted using IBM SPSS (Statistical Package for the Social Sciences) Version 25 and Microsoft Excel.

Results and discussion

Proximate composition: Since food and energy are necessary for our survival and long-term growth, more work must be done to utilize every square inch of land to cultivate and produce

enough food to feed the world's population (Xia and Yan, 2022). The results of unripe BARI Papaya-1 peel powder proximate composition (moisture, ash, protein, fat, fiber, and carbohydrate) are shown in Table 1.

Table 1. The proximate composition of BARI Papaya-1 peel powder

Parameters	Values (g 100 g^{-1})
Moisture	9.41± 0.26
Ash	6.33 ± 0.51
Protein	10.51 ± 0.35
Fat	1.10 ± 0.06
Crude Fiber	15.58 ± 0.33
Carbohydrate	57.07 ± 0.83
Energy (kcal)	280.24 ± 2.42

Values are mean ± standard deviation of three independent replications

The moisture content of the unripe BARI Papaya-1 peel was 9.41 ± 0.26 %. This study's findings are consistent with another study where it was reported (Egbuonu *et al.*, 2016) a moisture content of 8.04 ± 0.06 of papaya peel powder (Suchiritha Devi *et al.*, 2017), while another study reported the moisture content of papaya peel powder was 3.42 ± 0.03 %, which is low in comparison to our findings. The ash content of the papaya peel powder was 6.33 ± 0.51%. This finding was far higher than the ash content of apple peel powder (2.50 ± 0.35 %), an investigation carried out in another study (Khalid Saeed *et al.*, 2023). Considering the analysis of ash content, our study reveals a high likelihood of mineral presence in the selected papaya peels. In the dried peels of BARI Papaya-1, protein content was 10.51 ± 0.35 %. After analyzing two fruits (mango, apple) and two vegetables (bottle gourd, ridge gourd) peel protein content, Sadef *et al.* (2022) reported that ridge gourd peel contained the maximum protein content (16.5 ± 0.18 %). At the same time, the minimum level was observed in apple peel (1.24 ± 0.05 %).

The fat content in papaya peel powder was 1.10 ± 0.06 %. Dias *et al.* (2020) analyzed four fruit peel nutrient profiles. They reported that the fruit peel powders' lipid content varied from 0.47 ± 0.03 to 35.22 ± 0.58 %, with avocado having the greatest level and yellow passion fruit having the lowest. Another study revealed that the mango peel powder exhibited a fat percentage of 1.3 % (Dhankecha and Pandey, 2022) which conforms with our results. The crude fiber content of dried papaya peel was 15.58 ± 0.33 %. Hussein *et al.* (2015) reported some fruits and vegetable peels' crude fiber content ranging from 3.65 ± 0.02 to 12.15 ± 0.03 % and observed the greatest fiber content in mandarine peels which is in line with our analyzed result .

The examination of carbohydrates holds significant importance due to their role as a primary source of energy, accounting for more than 70% of total energy intake. The study of carbohydrates provides valuable insights into various aspects of food items, including their nutritional composition, adherence to standard identification requirements, water retention capabilities, flavor profiles, desirable textural attributes, and overall stability (Ali *et al.*, 2021). The carbohydrate and energy content of the analyzed dried papaya peel was 57.07 ± 0.83 % and 280.24 ± 2.42 kcal 100 g^{-1}, respectively (Table 1). .

Table 2. Vitamin concentrations of BARI Papaya-1 peel powder

Vitamin	Value in dry weight
Vitamin C (mg 100 g^{-1})	60.6 ± 0.73
β-Carotene (µg 100 g^{-1})	2952.08 ± 13.63
Vitamin A (RE 100 g^{-1})	246.01 ± 1.14

Values are mean ± standard deviation of three independent replications

Based on the findings of the study, it was observed that the dried papaya peels vitamin C concentration was 60.6 ± 0.73 mg 100 g^{-1} (Table 2). This result is comparable with other works where it was reported the vitamin C content of a few fruit peels ranged from 52.123 ± 0.255 to 110.56 ± 0.415 mg 100 g^{-1} (Mubasher Hussain *et al.*, 2023), while another study reported that the vitamin C content of lemon peels was found to be 58.59 mg 100 g^{-1} (Sir Elkhatim *et al.*, 2018). The concentration of β-carotene and vitamin A in the dried papaya peel were 2952.08 ± 13.63 µg 100 g^{-1} and 246.01 ± 1.14 RE 100 g^{-1}, respectively (Table 2). Our results mimic the results of another study where it was reported that the concentration of mango peel power was 3162 µg 100 g^{-1} (Ghosh *et al.*, 2019). Another study documented that the vitamin A content of mango peel was 100 RE 100 g^{-1} which is much lower than our investigated result (Lebaka *et al.*, 2021).

Antioxidant properties: This research investigation used a variety of antioxidant assays based on different processes to assess the papaya (*Carica papaya* L. var BARI Papaya-1) peel powder potential for antioxidants. The outcomes are displayed in Table 3. In our study, methanol was chosen as the extraction solvent because, for sample extraction, it is identified as the most powerful solvent, providing the greatest extraction yield of phytochemical constituents and antioxidants (Truong *et al.*, 2019).

Table 3. Antioxidant properties of BARI Papaya-1 peel powder

Parameters	Values in dry weight (DW)
Total Phenolic Content (mg GAE 100 g^{-1} DW)	1216.75 ± 18.87
Total Flavonoid Content (mg QE 100 g^{-1})	158 ± 3.12
Total Antioxidant Capacity (mg 100 g^{-1})	161.75 ± 2.13
DPPH radical scavenging (IC_{50}, µg mL^{-1})	36.79

Values are mean ± standard deviation of three independent replications
*IC_{50} value of Ascorbic acid = 7.39 µg mL^{-1}

According to our research, the dried papaya peel exhibited a total phenolic content of 1216.75 ± 18.87 mg GAE 100 g^{-1} (Table 3). The findings of this study are closely related to other studies, which documented a total phenolic content of 1394 mg GAE 100 g^{-1} in orange peel (Al-Saab and Gadallah, 2021). The flavonoid content displayed in Table 3 in dried peel was 158 ± 3.12 mg QE 100 g^{-1}. The total flavonoid content in orange peel was reported to be 93-994 mg QE 100 g^{-1} in a prior study (Fidrianny *et al.*, 2015) which is in line with our result. The antioxidant capacity of peels is demonstrated in Table 3 and the value was 161.75 ± 2.13 mg 100 g^{-1} DW. A prior study documented the total antioxidant capacity of 109.53 mg 100 g^{-1} in orange peel (Pallavi *et al.*, 2017) which is lower than our result. In contrast, Kumar *et al.* (2015) reported that the concentration of total antioxidant capacity in bottle gourd peel was 142.55 mg 100 $g^{-1,}$ which is consistent with our findings.

Papaya peel's DPPH radical scavenging activity at concentrations of 6.25 to 100 µg mL^{-1} were analyzed (Fig. 1). Radical inhibitory power (%) increased with the concentration. The figure depicted that papaya peel had a 74.41 % DPPH scavenging activity at 50 µg mL^{-1}, while standard ascorbic acid exhibited 92.99 % activity at the same concentration. Our investigation found that the IC_{50} value of dried papaya peel was 36.79 µg mL^{-1},

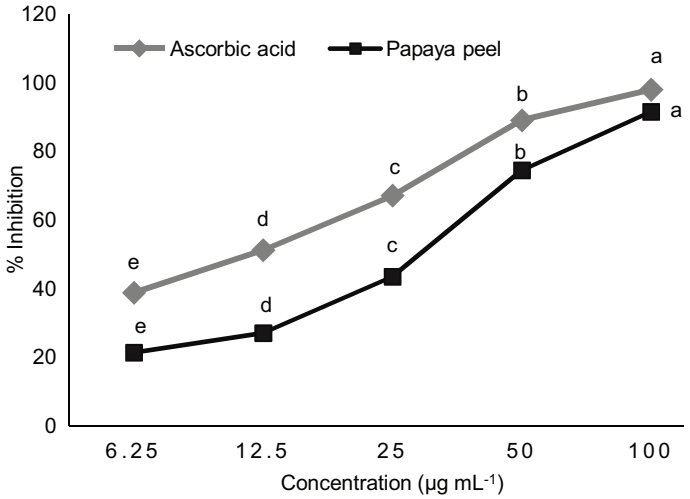

Fig. 1. DPPH radical scavenging activity of papaya peel powder at 6.25-100 µg mL^{-1} concentrations. The mean values in different uppercase letters are significantly ($P < 0.05$) different according to Duncan's Multiple Range test

while the standard ascorbic acid had an IC_{50} value of 7.39 µg mL^{-1} (Table 3). In a previous study, IC_{50} value of papaya peel extract was was reported as 18.5 µg mL^{-1} (Garg *et al.*, 2016) which was lower than our reported result, while banana peel had a 45.76 % DPPH scavenging activity at 50 µg mL^{-1} and an IC_{50} value of 56.22 µg mL^{-1} (Aboul-Enein *et al.*, 2016). The abundant presence of nutrients and antioxidants in the papaya peel powder, there is potential for their incorporation into food products to enhance their nutritional composition and mitigate oxidative stress.

This study revealed that unripe papaya peel powder, possessing significant antioxidant properties, can improve the nutritional quality of food products and function as a nutraceutical to combat malnutrition and supply exogenous antioxidants. Additional research is required to ascertain the specific compounds responsible for these antioxidant effects and their mechanisms, which could enhance our comprehension of the peel's function in mitigating cellular damage and promoting human health.

Acknowledgments

We want to thank all the participants for their cooperation and participation in this study. We are also grateful to the Bangladesh Council of Scientific and Industrial Research, Bangladesh, for providing the scope to conduct this study.

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Received: December, 2024; Revised: February, 2025; Accepted: February, 2025