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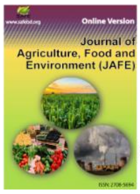

Research Article

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Unveiling nutritional and antioxidant potential of Burmese grape (*Baccaurea ramiflora* Lour.) peel extract in different solvents: a sustainable source of functional food development

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A B S T R A C T

The present study aims to unveil nutritional and antioxidant potential of Burmese grape (*Baccaurea ramiflora* Lour.)/lotkon peel, a common unexploited by-product. Proximate composition such as moisture content, crude protein, crude lipid, crude fat content was examined and phytochemical content like Total Phenolic Content (TPC), Total Flavonoid Content (TFC) as well as antioxidant potential such as phospomolybdenum and hydrogen peroxide(H_2O_2) assay was performed by solvent extraction method using pure methanol, pure ethanol and water. The Burmese grape fruit (BGF) peel contains high crude fiber (30.03%) and considerable protein levels of 9±0.27g/100g with low lipid content (0.87±0.04g/100g). The extraction efficiency of bioactive compound varied with the type of solvent used. Methanolic extract exhibit higher TPC and TFC content compare to ethanolic and water extract (67.28±0.55 µg of GA/g & 45.29±0.59µg of quercetin/g). Total antioxidant activity of peel extracts of different solvents exhibited antioxidant activities ranking from the order methanol > ethanol > water which have positive correlation between total phenolic content among different extracts. Ethanolic extract showed higher antioxidant activities in case of hydrogen peroxide inhibition test. The combined findings highlight the solvent selection on antioxidant recovery where ethanol and water extract are suitable for functional food grade application and methanolic for laboratory analysis. The study demonstrates that lokton peel which is commonly discarded as waste could be suitable source of natural bioactive compound contributing both waste valorization and functional food processing. Future perspective should involve the fusion of this valuable extract into food system and evaluate their health benefits through in vivo study.

INTRODUCTION

The growing global concerns over environmental sustainability and resource scarcity have led the food industry to recognize agri-food by-products, once considered waste, as valuable resources with significant untapped potential (Rațu *et al.*, 2023). Moreover, in current era, global food industry is facing challenges of meeting increasing demand for functional food and nutrients that provide health promoting effects along with the struggle of managing the generation of massive amount of agro-industrial waste which is a threaten for environment (Rana *et al.*, 2024). Different food process industries produce massive by products such as peel, seeds, pomace which often discharge as waste

(Balasundram *et al.*, 2006). Most of the waste used for animal feed or composting and some are decomposed in environments. In order to overcome this obstacle and satisfy the growing demand for food, modern agriculture is concentrating on the agro-processing industry to make the most use of these food wastes (Akter and Haque, 2019).

The generated waste specially fruit peel not only has appreciable number of nutrient components such as carbohydrate, protein, and vitamins but also easily biodegradable to environment. Because the peels of different fruits and vegetables contain phytonutrients that can be extracted and used in pharmaceutical, nutraceutical sectors, their chemical structure makes them a natural treasure source of valuable compounds with therapeutic benefits for humans (Dumitrascu *et al.*, 2024). Tropical fruit like banana, papaya, mango, are commonly disposed as by product despite of their abundant sources of polyphenol, phenol, dietary fiber and good antioxidant activity. These components are useful elements for food supplements and nutraceutical applications because of their strong antibacterial, anti-inflammatory, and antioxidant qualities (Mercatante *et al.*, 2024). Consumption of food rich in polyphenol and antioxidant in a long-term basis protects against certain chronic diseases such as cancers, cardiovascular diseases, type 2 diabetes etc (Gil *et al.*, 2024, Hrelia *et al.*, 2025). It is discovered by several studies that fruit and vegetable by-products, that are habitually wasted, have comparable or even better quantities of phytochemical compounds than edible fruit (Patra *et al.*, 2024). In the context of sustainability, utilization of these food waste helps to boost economy and sustainable food system by altering low value-added food into higher value products and also help to achieve international goal of "zero waste" (Sha *et al.*, 2023).

Recent studies have centered on the possibility of recovering the advantageous bioactive chemicals from fruit and vegetable peels and recycling them into products with a higher value and it becomes a newer research trend (Shanmugavadivu *et al.*, 2014; Kumar *et al.*, 2020).

Among the tropical fruits, lotkon or Burmese grape (*Baccaurea ramiflora*) is a significant evergreen, sluggish, fruit tree native to tropical and subtropical regions like Bangladesh, India, and other Southeast Asian countries. It has gained popularity recently due to its nutritional benefits and potential for bioprospection (Gogoi, 2017). The fruit and its peel both contain antioxidants and phenolics (Nurmayani *et al.*, 2021). This plant has also been cited in the Chinese Dai medicine. Various preliminary reports and traditional knowledge suggest that it is applied as an anti-inflammatory and painkiller in treatment of injuries, rheumatoid arthritis, cellulitis, abscesses *etc*. (Lin *et al.*, 2003). Minerals and vitamin C are abundant in this fruit, which has proven antioxidant properties and can help to eradicate a number of non-communicable diseases in a very economical manner. It contains approximately 36.11% peel of the whole weight (Rafi *et al.*, 2020). For a developing country like Bangladesh, lotkon is widely consumed as wild fruits, this fruit waste can specially peel can be processed into powder, extracted and concentrated and which can be used as functional food or natural preservation.

Although several research works have been conducted globally on the utilization of food waste such as mango peels, citrous peels, watermelon peel and many more, Burmese grape peel remains largely underexploited even much of this work has done without contributing a comprehensive sustainable approach (Nitisuk *et al.*, 2025; Ali *et al.*, 2025; Sani *et al.*, 2023; Firat *et al.*, 2023). Our study focused on evaluation of nutritional constituents like protein, lipid, dietary fiber of Burmese grape peel along with its phytochemical and antioxidant activity in three solvent extracts viz ethanol, methanol and water. Generally, extraction of bioactive compound is typically performed using solvent and their recovery from plant material depend on polarity and solubility of phenolics in the solvent (Muhamad *et al.*, 2014; Zhou and Yu, 2004). In this study, the inclusion of solvent based extraction as a comparative framework makes it differ from other conventional approaches. From sustainable perspective, utilization of Burmese grape (lotkon) peel could guide industries in choosing suitable extraction technologies depending on their desired application- whether it is for food grade purposes (water and ethanol) or high efficiency laboratory work.

MATERIALS AND METHODS

Processing of plant materials

The fresh Burmese grape fruit (BGF) was collected from local market and then washed with distilled water to remove foreign materials from the fruit surfaces. After that fruit were peeled, about 100g of fresh peel was subjected to determine moisture content. For determining crude protein, crude lipid, and crude fiber and for extract preparation, the peel was dried at 40°C in an oven dryer for 48h followed by grinding and sieving through 1.0 mm sieve into fine powder. The generated powders were stored in airtight containers and placed in a cool, dry and dark place until it is used for extraction.

(a)

(b)

Figure 1: a) oven drying of Burmese grape peel and b) fine powder of Burmese grape peel

Proximate composition

All evaluations were conducted on a dry weight basis (except for total moisture content). The dried Burmese grape peel powder was analyzed for crude lipid, crude protein, and crude fiber (%) using standard AOAC (1995) methods. The data were presented as mean ± standard deviation (SD), and the tests were conducted three times. The amount of crude protein was ascertained using the Kjeldahl technique. This process used H_2SO_4 digestion to convert the nitrogen in Burmese grape peel into ammonium sulfate, which is then alkalized with NaOH to produce ammonia. A known volume of a standard acid was used to distill ammonia. Titration was used to determine the residual acid, which represented the sample's nitrogen concentration (Formula 1).

The Total protein content = total nitrogen content × 6.25) ………………………………….. (1)

Burmese grape peel extracts preparation

The peel powder was subjected to solvent extraction, following the method of Sultana *et al.* (2022) with some alteration, to determine phytochemical content and antioxidant activity. Three different solvents such as pure ethanol, pure methanol, and distilled water used for the experiment. Each extraction was performed in a beaker by dissolving 4g lotkon peel powder in 100 mL solvent. For better extraction, the beakers were kept on an incubator shaker and allowed intermittent shaking at 37°C in the dark for 24h. After incubation, the solvent mixes were filtered through Whatman filter paper (20-25µm). The extracts were then condensed by Rotary Vacuum Evaporator at 36°C. The concentrated extracts were further dried to a 12 mg/mL concentration by bubbling nitrogen gas into the solution through nitrogen concentrator evaporator at 36°C.

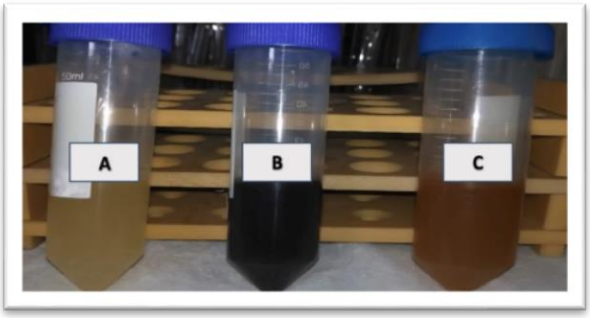

Figure 2: Peel extracts in different solvents; A) Water extract, B) Methanolic extract, C) Ethanolic extract

Burmese grape peel extract analysis

Determination of Total Phenolic Content

Folin-Ciocalteu phenol reagents and external gallic acid calibration were used to measure the total phenolic content (TPC) of crude extracts of peel from various solvents (Uddin *et al.*, 2018). 0.5 mL aliquot of the working solution was taken into each test tube then100µL of Folin–Ciocalteu reagent was added and the mixture was thoroughly mixed. The mixture was hold for 15 minutes in room temperature (25±2ºC). After that, 2.5 mL of saturated Na_2CO_3 was added in the test tube. After that the mixture was allowed to stand for 30 min at room temperature. Then the absorbance was measured at 760 nm using the spectrophotometer. Using GA standard solution (10 µg/mL to 50 µg/mL), a standard curve for TPC estimation was created using a similar process as previously mentioned. For each sample, the TPCs were stated as µg of gallic acid (GA) equivalents. To provide more precise results, analyses were done in triplicate.

Determination of Total Flavonoid Content

Total flavonoid contents (TFC) were determined using aluminium chloride colorimetric method with minor modifications (Liew *et al.*, 2018; Uddin *et al.*, 2018). After transferring 1 mL of each sample into a separate test tube, 3 mL of methanol, 0.2 mL of a 10% aluminum chloride solution, 200 µL of 1 M potassium acetate, and 5.6 mL of distilled water were added one after the other. The mixtures were then thoroughly mixed and then the test tubes were let to stand at room temperature (25±2ºC) for 30 minutes. A spectrophotometer was used to test each content's absorbance at a wavelength of 420 nm. TFCs were expressed as µg of quercetin equivalents per g of the sample.

Evaluation of Antioxidant Activity

Phosphomolybdenum Assay

The antioxidant activity of different extracts was calculated by the method of Prieto *et al.* (1999) which has been followed by relevant research groups such as Rafiquzzaman *et al.* (2016); Uddin *et al.* (2018). In separate test tubes, 0.9 mL of the working reagent solution (0.6M H_2SO_4, 28mM sodium phosphate, and 4mM ammonium molybdate) was taken. In different test tubes, 100 µL of standard solutions with varying concentrations and diluted working extracts of various solvents were obtained. The test tubes were immersed in a boiling water bath at 95°C for 90 minutes after being sealed and coated with aluminum foil sheets. The same solvent (ethanol/methanol/water) and 0.9 mL of reagent solution were used to run the blank, which was then incubated like the other samples. The absorbance value at 695 nm was used to express the overall antioxidant activity. Higher sample extract absorbance is correlated with stronger antioxidant activity.

Hydrogen Peroxide Scavenging Activity

With minor adjustments, the hydrogen peroxide scavenging activity was used to assess the antioxidant activities using the methodology of Jadhav (2020). This method has been proved to be useful by many research groups Rafiquzzaman *et al.* (2016); Saha *et al.* (2016). 500µl of dilute extract of peel and standard solution of varying concentration were taken in different test tubes. 0.3 mL hydrogen peroxide (H_2O_2) solution and 1.2 mL phosphate buffer were added in every test tube. The mixtures were then vortex well and allowed to stand for 10 minutes at room temperature. After 10 min the absorbance was measured at 230 nm using a spectrophotometer against a blank solution (solvent). The control solution was prepared using the test sample (0.3 mL) and phosphate buffer (1.2 mL) for every individual concentration of test sample. The following formula (2) was used to calculated the percentage inhibition of different peel extracts, Hydrogen peroxide (H_2O_2) scavenged (%) = [(A_0 – A_1)/(A_0)] × 100 ………………………..(2)

Where, A_0 is the absorbance of control + phosphate buffer and A_1 is the absorbance of sample solution which is the sample + phosphate buffer + hydrogen peroxide. The final result was compared with % radical scavenging activity of standard solution (Ascorbic acid).

Statistical Analysis

Each test was carried out three times and the average values are reported in the ensuing sections. All the data are presented as mean ± SD. One-way analysis of variance was used to assess the significant difference between two mean values at a 95% confidence level ($p < 0.05$).

RESULTS AND DISCUSSION

Proximate composition of Burmese grape peel

The proximate values of the Burmese grape peel sample are given in table 1. All the evaluation were recorded on dry basis (except total moisture content). The mean moisture content of the Burmese grape peel was 40.97 ± 0.12 g/100 g, while the crude protein and crude lipid contents were 9± 0.27 g/100 g and 0.87 ± 0.04 g/100 g, respectively. According to Mann *et al.* (2016) Burmese grape had negligible content of fat in its pulp and peel also the total protein content was 3.69% and 9.31%, respectively. The peel contains 30.2% crude fiber content. Highest fiber content from Burmese grape peel was 79.94 ± 0.41 g/100 g, obtained by Saikia and Mahanta (2016). The variance of fiber content of different or same fruit may be due to physiological factors like species, ripeness of fruit etc. Overall, the peel is a good source of crude fiber (%) with moderate crude protein and low crude lipid content. These findings give us a clear consideration that this usual by-product can be a significant source of nutrients if it is utilized properly.

According to the table 1, the protein content of Burmese grape peel was comparatively high compared to several fruits peel, which generally have lower protein level. Pacheco-Jiménez *et al.* (2024), found 2.27-2.62g protein from mango peel from Mexican cultivars, whereas Belose *et al.* (2021) found that orange peel contains approximately 5.34g protein which is lower than our finding.

Table 1: Proximate composition of the dried samples (Mean±SD)

Burmese grape peel	Moisture content (g/100g)	Crude protein (g/100g)	Crude lipid (g/100g)	Crude fiber %
Mean ±SD	40.97±0.12	9±0.27	0.87±0.04	30.03±0.23

All values are expressed as mean ± standard deviation (SD).

This result indicates that Burmese grape peel can be alternative source of protein that can be incorporate in functional food. The crude lipid content in the peel sample is low (0.87±0.04g/100g) but this result also supports Gul *et al.* (2023) who found approximately 0.78% of crude fat from orange peel powder so it is consistent with the general composition of fruit peel. The Burmese grape peel contains excellent amount of fiber content and the value is comparable with other research finding such as papaya peel (37.91 ± 0.90%) and banana peel (34.80±3.80%) (Gopalraaj and Velayudhannair, 2025 & Youssef *et al.*, 2024). This high fiber level is particularly crucial for improving digestive health, reducing cholesterol level and increasing a scope for Burmese grape peel as a functional food ingredient.

Total phenolic content (TPC) and Total flavonoid content (TFC)

Table 2 displays the amount of TPC content found in various solvent extracts of Burmese grape peel. Result revealed that methanolic extract contained higher amount of phenolic content (67.28±0.55µg GA/g) followed by other two extracts. Ethanolic extract contained 39.36±0.43 µg of GA/g and water extract contained 13.72±0.76 µg of GA/g of TPC respectively.

Table 2: Total phenolic and flavonoid contents of different extracts of peel of Burmese grape (Mean±SD)

Sample	Solvent extract	TPC (µg of GA/g)	TFC (µg of quercetin/g)
BGF peel	Ethanolic	39.36±0.43	37.70±0.46
	Methanolic	67.28±0.55	45.29±0.59
	Water	13.72±0.76	14.08±0.72

All values are expressed as mean ± standard deviation (SD).

From all peel extract of three solvents, methanolic extract (45.29±0.59 µg of quercetin/g) contain higher flavonoid content compare to ethanol extract (37.70±0.46µg of quercetin/g) and water extract (14.08±0.72µg of quercetin/g). Uddin *et al.* (2018) conduct a study where phytochemical analysis of Burmese grape peel, pulp and seed on methanolic extract was performed where they found 47.230 ± 3.703 mg GA/g) of TPC and 20.720 ± 1.226 mg GA/g) of TFC from peel extract.

Alam *et al.* (2008) also published the similar statement where in different solvent concentrations (50% methanol, 50% ethanol, 50% acetone), 50% methanol had the highest amounts of TPC (425.55±0.19a and 321.54±0.12a mg GA/100g dry weight) in longon and lotkon peel extracts respectively. In case of the TFC, the yields by extraction solvents were as follows, from highest to lowest: 50% methanol >50% ethanol>50% acetone. These findings also match with El-Hadary & Taha, (2020) where they used petroleum ether, ethyl acetate, ethanol 80% (v/v), methanol 80% (v/v), and water as solvent to extract pomegranate peel in which methanol was the highest competent solvent for the phenol and flavonoid compound.

Because of the complexity of chemicals, process of extraction and analysis techniques, several authors have reported significant differences in the TPC and TFC of the same fruits. Variation of TPC also found due to use of different solvent because solubility of any phenolic compounds attribute to any specific solvent. Phenolic compounds are usually more soluble in polar organic solvents compared to the water (Rajauria *et al.*, 2013). Numerous extrinsic (agronomic, environmental, handling, and storage) and intrinsic (genus, species, and cultivar) factors also affect the phenolic levels of plants (Tomás-

Barberán *et al.*, 2001). Methanol better extraction characteristics can be attributed to its intermediate polarity and ability to penetrate plant cell which is result in higher solubilization of phenolic and flavonoid compound. Although ethanol and water extract exhibit lower TPC and TFC than methanol, this are generally recognized as safe solvent and widely accepted for food, nutraceutical and pharmaceutical application (Chemat *et al.*, 2019). However, variation found in TPC and TFC across the solvents suggest the necessity of selecting solvents based on the intended use of the extracts. Water-based extract are important applicants in beverage, functional food and formulation specially where there is a demand for clean and chemical free products. Overall findings propose that Burmese grape peel is a rich source of phenolic and flavonoid compound and their recovery is depended on the choice of extraction solvent.

Total antioxidant capacity

Evaluation of total antioxidant activities of different extract of Burmese grape peel were observed using the Phosphomolybdenum assay, and inhibition percentage was determined by Hydrogen peroxide scavenging assay.

Phosphomolybdenum Assay

The total antioxidant capacity of extracts has frequently been assessed using the phosphomolybdate assay. This technique relies on sodium sulfide's conversion of phosphomolybdic acid to phosphomolybdenum blue complex. In addition of nitrite oxidizes the resulting phosphomolybdenum blue complex reduces the blue color's intensity (Prieto *et al.*, 1999). The phosphomolybdenum assay of Burmese grape were extract and concentration reliance but the extent of activity varied depending on the solvent used. Here methanolic extract even at the lowest concentration showed the highest absorbance at 695 nm wavelength because of its polarity followed by other two peel extracts of different solvents (Figure 3). However, ethanol and water extract can still be beneficial for food grade status. A standard calibration curve was also made using ascorbic acid as a positive control for phosphomolybdenum assay. The solution turns a deep blue color when antioxidant activity is present. Figure 3 displayed the number of ascorbic acid equivalents for antioxidant activity of each extract.

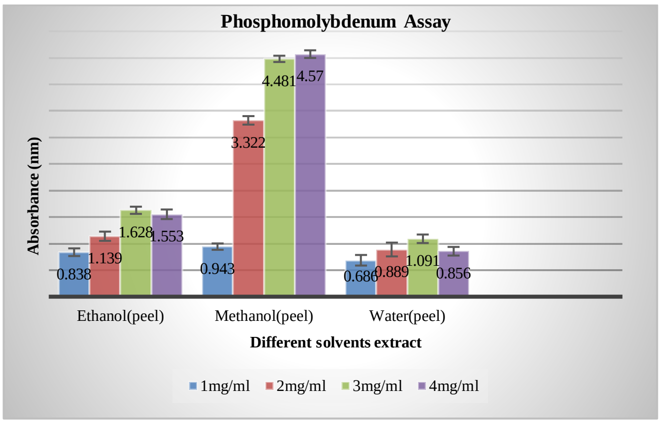

Figure 3: Total antioxidant activities capacity of ethanolic, methanolic and water extract of Burmese grape peel

Hydrogen peroxide inhibition activity

The ability of antioxidant actions of extracts of Burmese grape peel was also assessed by the hydrogen peroxide scavenging activity. Hydrogen peroxide could be scavenged by all of the extracts in a concentration-dependent manner. Figure 4 showed that the highest activity was in the ethanolic extract of peel followed methanolic extract and water extract of peel. The lowest scavenging activity was observed in water extract of peel. A standard calibration curve was also prepared using ascorbic acid as a positive control for hydrogen peroxide scavenging assay. This curve showed the comparison of the antioxidant activities of ascorbic acid with test samples.

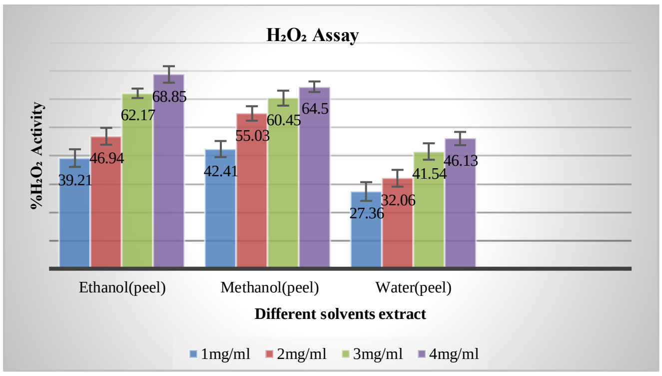

Figure 4: Percentages of hydrogen peroxide scavenging activities of different peel extract

The findings showed that the extracts' activity was dose-dependent, which implies that % scavenging activities of any substances increased with increasing concentration of this substances. The study also revealed that peel extract of different solvents exhibited a remarkable antioxidant activity ranking from the order methanol> ethanol>water. In case of hydrogen peroxide scavenging activity, ethanolic extract of the peel have higher antioxidant activity followed by other samples.

There is a positive correlation of antioxidant capacities of Burmese grape extract with phenolic and flavonoid contents in the extracts. This correlation of extract antioxidant activities with phenolic content was similar with the report of Alothman *et al.* (2009). Antioxidant activities of any extract depend on the solvent used and most of the literature reported that methanolic, ethanolic extract possess higher antioxidant activities compare to water extract (Rafiquzzaman *et al.*, 2016). Higher antioxidant activities also may be due to the presence of other compounds in peel extracts; and it has also been stated that solvents used for extraction have intense effect on the chemical or biochemical type (Yuan *et al.*, 2005). Antioxidant activity and phytochemicals present in plants are also triggered by a number of internal-external factors and also physiological characteristics of plant (Tomás-Barberán *et al.*, 2001).

The combination of H_2O_2 scavenging assay and phosphomolybdenum assay give positive insight into antioxidant potential of Burmese grape peel. Most of the study employ DPPH or ABTS assays, this study uses two other methods to evaluate their activity level towards food extract. Valorization of such bioactive rich by products not only a great alternative to synthetic preservatives but also could play important role in value added food system.

Credit of authorship contribution statement

Conceptualization: R. Sultana, MA Haque; Methodology: R. Sultana, MA Haque; Experiment management and data collection: R. Sultana, S. T. Dola, Jannatul N; Data analysis: R. Sultana, JA Farhana, Jannatul N; Writing-original draft preparation: R. Sultana, Jannatul N; Writing- review and editing: MA Haque, JA Farhana; Supervision: MA Haque, R. Sultana; The final manuscript has been read and approved by all writers.

Conflict of interest

The authors declare no conflict of interest.

CONCLUSION

The current study highlights *Baccaurea ramiflora* (Burmese grape) peel as an underutilized fruit by-product with remarkable nutritional and functional potential. The peel was found to contain high levels of protein and crude fiber, making it a promising source of essential nutrients for food development. In this study, solvent extraction exhibited vital role in determining the phenolic, flavonoid, and antioxidant activities of the peel extracts. The antioxidant potential of various Burmese grape peel extracts was confirmed through two assays: the phosphomolybdenum method and the hydrogen peroxide scavenging assay. Among the tested solvents, antioxidant activities followed the order methanol > ethanol > water, which was consistent with the ranking of both total phenolic content and total flavonoid content. The presence of diverse bioactive compounds and their medicinal properties provide strong scientific support for the therapeutic claims associated with Burmese grape. Overall, these findings suggest that the peel can be recognized as a valuable functional ingredient, rich in antioxidants, crude fiber, and protein. Beyond its nutritional and functional benefits, the utilization of this by-product also helps to downgrade waste and promotes the sustainable use of agro-industrial residues. These results can serve as a guideline for future research focused on developing low-cost, practical, and innovative food technologies using Burmese grape peel.

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