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Comparative Study of the Nutraceutical and Photoprotective Properties of Ethanolic Extracts from Peel and Pulp of Mango (*Mangifera indica* L. cv. TomEJC)

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This research investigated the nutraceutical and photoprotective properties of ethanolic extracts obtained from the peel and pulp of *Mangifera indica* L. 'TomEJC' cultivar. Phytochemical screening indicated the presence of phenols, alkaloids, cardiac glycosides, saponins and coumarins. The mango peel exhibited higher total phenolics (17.69 ± 0.51 mg of GAE per g of dry weight), flavonoid content (13.39 ± 0.43 mg of QE per g of dry weight), antioxidant activity (IC_{50} = 76.96 ± 5.11 µg/mL) and crude fiber content (15.66 ± 0.28%) compared to the pulp. The peel extract showed a higher sun protection factor (31.10 ± 1.18) compared to the pulp extract (2.00 ± 0.20), indicating strong UV-B absorption. GC/MS analysis identified several volatile compounds with known bioactivities in the peel extract. Findings suggest that TomEJC mango peel possesses superior nutraceutical and photoprotective properties compared to the pulp, highlighting its potential for applications in the herbal nutraceutical and cosmetic-pharmaceutical industries.

Keywords: *Mangifera indica*, TomEJC cultivar, Mango peel, Antioxidant activity, Photoprotective properties.

INTRODUCTION

Mango (*Mangifera indica* L.) belongs to the family Anacardiaceae, has a cultivation history in Asia spanning more than 4,000 years. The main mango varieties leading the global export market are Tommy Atkins, Kent, Haden, Ataulfo, Keitt and Alphonso [1]. Mango has an attractive taste, aroma and high nutritional value. These unique characteristics set the mango apart from other fruits, earning it the title "The king of the fruits" [2]. The evergreen mango tree thrives in tropical and subtropical climates and is therefore cultivated worldwide. Asia is the leading producer of mangoes, with India being a major exporter. India's annual mango production has reached approximately 24 million tons [3]. While there are more than 1,000 mango varieties globally, Solís-Fuentes & Durán-de-Bazúa [4] reported that only a limited number are cultivated on a commercial scale and traded internationally.

In Sri Lanka, the main mango-producing districts are Kurunegala, Gampaha, Ratnapura, Hambantota, Monaragala, Matale, Puttalam and Matara. The area devoted to mango cultivation is about 30,000 hectares, with an estimated annual yield of 186,663 tonnes [5]. According to records of the Department of Agriculture, the recommended cultivars are Karthakolomban, Velleikolomban, Willard/Villard, TJC/TomJC, Giraamba, Malwana, Dampara and Horanahiru [6]. In addition, commonly cultivated varieties such as Kohu, Betti, Polamba and Amrapalavi are also found across the country [7].

Among the mango varieties grown in Sri Lanka, the Tom EJC (TJC) cultivar shows significant potential for export due to its large fruit size, golden-orange colour, juicy flesh, fibre-less texture and excellent taste [3,8]. The Tom EJC cultivar possesses distinct characteristics that contribute to its popularity among the mango types endorsed for cultivation in Sri Lanka. It is recognized as the juiciest and largest variety, featuring a smooth, aromatic flesh with low fiber content and a clear skin [9]. Moreover, Tom EJC is regarded as a consistent and heavy bearer of high-quality fruits [10]. The Tom EJC mango exhibits a slow ripening pattern, typically requiring approximately two weeks post-harvest to reach the table-ripe stage. This extended ripening period allows sufficient time for transportation to market. Within the promising mango cultivars found in Sri Lanka, Tom EJC is regarded as the most suitable for export [11].

Mango peels constitute a significant portion of agro-industrial waste generated during mango processing. Currently,

these peels are often discarded, posing potential environmental risks due to their contribution to pollution. Mango peels are rich in bioactive compounds such as carotenoids, polyphenols, vitamins C and E, dietary fiber, and enzymes and exhibit strong antioxidant activity [12]. Thus, exploring their bioactive potential is therefore valuable. Such studies can add the value of this waste product and open avenues for new research and commercial applications, supporting national development and scientific advancement. However, research on the nutraceutical and photoprotective properties of TomEJC mango peel remains limited.

The main objective of this study was to extract bioactive compounds from the peels and pulp of the Tom EJC mango, to evaluate the nutraceutical and photo-protective properties of the chemical constituents present in the peel and to compare them with those of the pulp. A specific objective of the study was to extract chemical constituents from the peel and pulp of mango (*Mangifera indica* L. cv. TomEJC) using Soxhlet extraction with ethanol and to conduct phytochemical screening tests on the extracts. Other specific objectives were to determine the total phenolic content, total flavonoid content, antioxidant activity using DPPH free radical scavenging assay, percentage of crude fiber, *in vitro* sun protection factor (SPF) of both the extracts and evaluate the photostability of the extract with the highest *in vitro* SPF. In addition, the study focused on identifying the volatile constituents found in the ethanolic extract of TomEJC mango peel using gas chromatography-mass spectrometry (GC/MS).

EXPERIMENTAL

Sample collection and pretreatment: Ripen fruits of the TomEJC mango variety were purchased from various local markets in the Gampaha district of Sri Lanka between November and December 2021. After rinsing with tap water, the fruits were air-dried at room temperature. Mango peels were manually separated from the fruits, cut into smaller pieces and air-dried in a shaded area for six days. The pulp was chopped into small cube-shaped pieces and similarly air-dried in the shade for 20 days. Once dried, the peel and pulp were ground separately into fine powders using a mechanical grinder. The powders were separately enclosed in airtight bags and refrigerated at 4 ºC until further use.

Extraction: Using a Soxhlet apparatus, 20 g of mango peel powder and 20 g of mango pulp were extracted individually with 100 mL of ethanol for 6 h, until the siphon tube extracts became colourless. Solvents were filtered and evaporated using a rotary evaporator at 37 ºC. The crude extracts were stored at 4 ºC until needed.

Phytochemical screening: The mango peel and pulp extracts were subjected to phytochemical screening following the procedures described by Priyanka *et al*. [13]. The analysis included tests for a wide range of bioactive compounds, for example, tannins, steroids, proteins (using xanthoproteic test), phenols (ferric chloride test), phytosterols (Salkowski's test), anthocyanins, cardiac glycosides (Keller-Killani test), saponins, coumarins, alkaloids, amino acids (Ninhydrin test), leucoanthocyanins and phlobatannins. Each test was performed according to established protocols to qualitatively detect the presence of these phytochemicals in the extracts.

Determination of total phenolic content: The Folin-Ciocalteu method was employed to determine the total phenolic content (TPC) in the ethanolic extracts of both pulp and peel as described by Abbasi *et al.* [14], with some modifications. 0.50 mL of each sample was mixed with 2.50 mL of 10% (v/v) Folin-Ciocalteu reagent. The solution was left in dark for 8 min followed by the addition of 2 mL of Na_2CO_3 (7.5%, w/v) and then kept the solution in dark for 1 h. The absorbance at 765 nm was determined using a UV-Visible spectrophotometer (Thermo-Scientific). Ethanol was used as the blank. Six concentrations of gallic acid (10, 20, 40, 60, 80, 100 mg/kg) were prepared to construct the calibration curve. TPC was calculated by the calibration curve (R^2 = 0.9942) and expressed as mg gallic acid equivalents per gram of dried weight of plant material (mg GAE/g dw). All samples were analyzed in triplicate.

Determination of total flavonoid content: Total flavonoid content (TFC) of ethanolic extracts from pulp and peel samples was determined using the aluminum chloride colorimetric assay as described by Sulaiman & Balachandran [15] with minor modifications. Each sample (0.50 mL) was mixed with 2 mL of distilled water and 0.15 mL of aqueous sodium nitrite solution (5% w/v) was added and left to stand for 6 min. Aqueous $AlCl_3$ (10% w/v of 0.15 mL) was added and allowed to stand again for 6 min, followed by the addition of 2 mL of aqueous NaOH, 4% w/v solution. The final volume was brought up to 5 mL with distilled water. The reaction mixture was thoroughly mixed and then allowed to stand for an additional 15 min. Using a UV-Visible spectrophotometer (Thermo-Scientific), the absorbance of the mixture was determined at 415 nm. Quercetin was used as the standard and TFC was calculated using the calibration curve of quercetin (R^2 = 0.9994) and expressed as mg quercetin equivalent (QE) per g dry weight of plant material. A standard series of quercetin (100-1000 mg/L) was prepared and distilled water was added to bring the final volume up to 5 mL and thereafter treated in the same way as the sample. All experiments were carried out in triplicate.

DPPH free radical scavenging activity: Extracts were evaluated in a 96-well microtiter plate following the method of Chatatikun & Chiabchalard [16] with minor modifications. A stock solution of the sample and the standard butylated hydroxytoluene (BHT) at 1000 µg/mL were prepared and subsequently diluted to a final concentration of 1000, 500, 250, 125, 62.5, 31.25, 15.62 and 7.81 µg/mL. Methanolic DPPH solution (0.25 mg/mL of 40 µL) was added to each sample solution and to 160 µL of standard solution in the well plate and incubated for 30 min at room temperature in a dark condition. The absorbance of each well was recorded at 517 nm with a microtiter plate reader. (Thermo-Fisher Scientific). A control sample consisted of 160 µL of methanol and 40 µL of DPPH, while 200 µL of methanol was used as the blank sample. The percentage inhibition was determined using eqn. 1:

$$\text{Inhibition } (\%) = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \quad (1)$$

where the absorbance is denoted as A. The calculated % inhibition values were plotted against the corresponding sample or standard concentrations to determine the IC_{50}.

Crude fiber content: Mango peel and pulp samples, after oven drying and defatting, were individually analyzed for crude fiber content. In this experiment, the standard crude fiber estimation method described by the AOAC, 2000 [17] was employed. 2.00 g of each sample was taken into a 1000 mL beaker. Sulphuric acid (200 mL of 1.25%) was added and digested by boiling for 30 min. The digested material was filtered using Whatman no. 42 filter paper and then the residues were washed with hot water at boiling temperature to make the sample acid-free. Finally, 200 mL of NaOH (1.25%) was added to the sample and boiled for 30 min in order to perform an alkali digestion. Residues were filtered again and rinsed with hot water, transferred to pre-weighed crucibles for drying and charring. Charred samples were subjected to ignition at a temperature of 400 ºC for 6 h to obtain ash. The crucibles were then cooled and reweighed. The weight reduction was recorded as the crude fiber content of the sample. The crude fiber percentage was calculated using eqn. 2:

$$\text{Crude fiber (\%)} = \frac{\text{Weight of residue} - \text{Weight of ash}}{\text{Weight of sample}} \times 100 \quad (2)$$

***In vitro* sun protection factor and photostability:** The extracts of peel and pulp were redissolved in ethanol separately for the preparation of 3.0 mg/mL solutions. A reference sunscreen (a commercial sunscreen product) was dissolved in ethanol to prepare a 3.0 mg/mL solution. The UV absorbance of each solution was measured over the wavelength range of 290 to 320 nm, at 5 nm intervals using a UV-Visible spectrophotometer (Thermo-Scientific). Each experiment was conducted in triplicate. Ethanol was used as the blank. *In vitro* sun protection factor (SPF) of both samples and reference was determined using eqn. 3:

$$\text{SPF} = \text{CF} \times \sum_{290}^{320} \text{EE}(\lambda) \times \text{I}(\lambda) \times \text{Abs}(\lambda) \quad (3)$$

CF is the correction factor (= 10); λ denotes the wavelength; and I represents the solar intensity spectrum. In this context, the erythemal effect spectrum is denoted as EE and the absorbance of the extract/sunscreen product is denoted as Abs.

The peel extract sample and the reference were exposed to direct sunlight for 21 days and UV absorbance was measured on the 7th, 14th and 21st days to assess its photostability [18].

GC/MS analysis of ethanolic extract of peel: Volatile chemical constituents of the extract of the peel of mango dissolved in dichloromethane were analyzed using a gas chromatography system (Agilent Technologies 7890B, USA) equipped with a mass spectrometer (Agilent Technologies 5977B MSD, USA). The system was fitted with a capillary column (Agilent 19091s – 433 HP-5MS UI 5% phenyl methyl siloxane) with dimensions of 30 m × 0.25 mm × 0.25 μm film thickness and a split injector. Positive electron impact mode with 70 EV was used for the analysis. The injector temperature was maintained at 150 ºC. For the oven thermal programming, the starting temperature was maintained at 50 ºC for 3 min. The temperature was then raised to 280 ºC at a heating rate of 10 ºC/min. The temperature of the transfer line and ion source was controlled at 50 ºC. Helium served as the carrier gas at a flow rate of 3 mL/min in splitless mode, with 1 μL of sample injected. The volatile compounds in the peel extract were identified using the National Institute of Standards and Technology (NIST) library. In this study, only compounds with a matching quality score exceeding 75% were considered for reporting.

Statistical analysis: Data are expressed as mean ± standard deviation (SD) based on three independent experiments, each conducted in triplicate. Results were processed statistically using GraphPad Prism 9.3.1 statistical software. Significant differences were evaluated using Tukey's pairwise test following ANOVA. Values achieving $p < 0.05$ were regarded as significant.

RESULTS AND DISCUSSION

The highest yield of 66.95% was obtained from the ethanolic extract of pulp, whereas a lower yield of 20.20% was obtained from the ethanolic extract of peel. Qualitative analysis of the ethanol extracts indicated the presence of proteins, phenols, coumarins, cardiac glycosides, saponins and alkaloids in both mango peel and pulp. Moreover, tannins were detected in the mango peel but were absent in the pulp. Steroids, phytosterols, anthocyanins, amino acids, phlobatannins and leucoanthocyanins were not detected in either the peel or the pulp. Table-1 summarizes the results of phytochemical screening of the TomEJC cultivar of mango (*M. indica* L.) peel and pulp.

TABLE-1
PHYTOCHEMICAL SCREENING RESULTS OF THE TomEJC CULTIVAR OF MANGO (*Mangifera indica* L.) PEEL AND PULP

Compound	Test	Peel extract	Pulp extract
Tannin	Lead acetate	Present	Absent
	Ferric chloride	Present	Absent
Steroid	Salkowski test	Absent	Absent
Proteins	Xanthoproteic test	Present	Present
Phenol	Ferric chloride test	Present	Present
Phytosterol	Salkowski's test	Absent	Absent
Anthocyanin	Ammonia test	Absent	Absent
Cardial glycosides	Keller-Killani test	Present	Present
Coumarin	Alkaline reagent test	Present	Present
Alkaloids	Wagner test	Present	Present
	Hager's test	Present	Present
Saponin	Foam test/froth test	Present	Present
Amino acids	Ninhydrin test	Absent	Absent
Phlobatannins	HCl test	Absent	Absent
Leucoanthocyanin	Acid hydrolysis test	Absent	Absent

Total phenolic content (TPC): In present study, the ethanolic extract of mango peel showed a higher TPC of 17.69 ± 0.51 mg of GAE per g of dry weight compared to that of mango pulp (10.57 ± 0.57 mg of GAE per g of dry weight). A previous study reported the TPC of the peel of the Willard mango variety as 275.61 ± 5.24 mg GAE/g of dry weight of the extract. The TPC of pulp of the same mango variety was reported as 110.88 ± 6.62 mg GAE/g of dry weight of the extract. Whereas the TPC of peel and pulp of mango variety Vellaicolomban was reported as 52.67 ± 2.43 mg GAE/g and 16.67 ± 3.34 mg GAE/g of dry weight of extract, respect-

ively. In the same study, TPC of peel and pulp of mango variety Karuthacolomban was reported as 86.69 ± 3.25 mg GAE/g and 31.36 ± 3.84 mg GAE/g of dry weight of extract, respectively. In this study, ethyl acetate was used as solvent for the extraction. Vellaicolomban and Karuthacolomban are mango varieties native to Sri Lanka, while Willard was introduced later from Mauritius [19].

Another study conducted in Korea reported that the TPC of 80% ethanol extracts from ripe mango peel and pulp was 70.1 ± 4.61 mg GAE/g and 26.9 ± 3.76 mg GAE/g, respectively [20]. The results were expressed as gallic acid equivalents (GAE) in mg/g of dried plant material. A previous study was conducted using nine mango varieties, namely Golden Water Lily, Rainbow, Chokanan, Golden Phoenix, Susu, Farlan, Aust R2E2, Telur and Harumanis. The TPC of ethanol extract of peel of these nine varieties was reported as 2212, 2642, 840.4, 1320, 1457, 1982, 2610, 2692 and 881.2 GAE (mg/100 g), respectively. TPC of ethanol extract of pulp of the same varieties was reported as 1098, 787.6, 1090, 274.6, 463.2, 665.8, 1267, 1032 and 640 GAE (mg/100 g), respectively [21]. The results showed that in eight out of the nine mango varieties tested, the total phenolic content was consistently higher in the peel than in the pulp, with only one variety exhibiting the opposite trend.

Total flavonoid content (TFC): In this study, the TFC of the ethanolic extract of mango peel was substantially higher (13.39 ± 0.43 mg QE per g of dry weight) than that of the pulp (1.05 ± 0.94 mg QE per g of dry weight). These findings clearly indicate that mango peel contains a considerably greater concentration of flavonoid compounds than the pulp.

A previous study conducted in Sri Lanka, reported the significant differences in flavonoid levels among three mango varieties [22]. In Willard, the peel contained 140.56 ± 14.23 mg QE/g, while the pulp measured 120.20 ± 10.29 mg QE/g. For Vellaicolomban, the peel and pulp values were 161.92 ±27.10 mg QE/g and 479.80 ± 15.30 mg QE/g, respectively. Karuthacolomban showed 187.65 ± 17.05 mg QE/g in the peel and 176.70 ± 40.97 mg QE/g in the pulp. These results indicate that Willard & Karuthacolomban had higher flavonoid concentrations in the peel than pulp, whereas Vellaicolomban displayed the opposite trend. In another study conducted in China [14], it is reported that TFC of peel of nine mango varieties, namely Luzon, Royal, Narcissus, Keitt, Big Tainong, Australian mango, Thai mango, Small Tainong and egg mango ranged from 19.91 ± 0.70 to 75.35 ± 2.68 mg of catechin equivalents (CE) per 100 g of fresh weight (FW). TFC in pulp samples of the same mango varieties ranged from 0.904 ± 0.07 to 9.252 ± 0.18 mg of CE per 100 g of FW [15]. The TFC of the peel of each mango variety was higher than that of the pulp of the same variety on a fresh weight basis. In India, Muralidhara *et al.* [12] demonstrated that the TFC was significantly lower in mango pulp compared to mango peel across the five mango varieties tested. The TFC of peel ranged from 76.87-310.07 mg QE/100 g in fresh weight, whereas the TFC of pulp ranged from 7.00-37.07 mg QE/100 g in fresh weight.

DPPH free radical scavenging activity: Fig. 1 shows the antioxidant activity of the ethanol extract of mango peel and pulp, along with the antioxidant activity of the positive control, BHT. Table-2 represents the IC_{50} values of BHT, extracts of mango peel and mango pulp. The highest antioxidant activity was given by the standard (BHT) with an IC_{50} of 8.01 ± 0.42 µg/mL. The ethanolic extract of peel showed higher antioxidant activity than that of the extract of pulp. A previous study conducted in Sri Lanka reported that IC_{50} values of peel and pulp of Willard mango variety were 11.86 ± 0.33 µg/mL and 24.67 ± 0.88 µg/mL respectively [19]. In the same study, it was reported that IC_{50} values of peel and pulp of Karuthacolomban mango variety were 14.86 ± 2.70 µg/mL and >500 µg/mL, respectively [19]. This reveals that the antioxidant activity of the peel is higher than that of pulp in both Willard and Karuthacolomban mango varieties. Therefore, mango peels, which are typically discarded, could be repurposed as an abundant source of natural antioxidants for use in nutraceuticals, functional foods or cosmetic formulations.

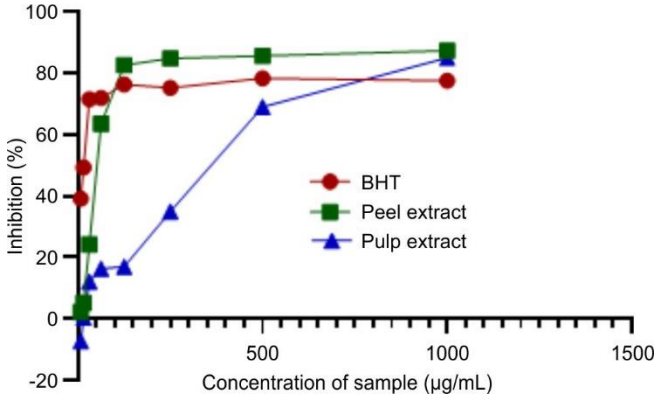

Fig. 1. DPPH free radical scavenging activity (% inhibition) of ethanolic extracts of mango peel and pulp

TABLE-2
IC_{50} VALUES OF ETHANOL EXTRACTS OF MANGO PEEL AND PULP

Sample	IC_{50} (µg/mL)
BHT (standard)	8.01 ± 0.42^{a}
Peel extract	76.96 ± 5.11^{b}
Pulp extract	282.21 ± 16.60^{c}

Note: The samples were tested in triplicate (n = 3) and expressed as mean ± standard deviation. Values with distinct superscript letters indicate significant differences at $p < 0.05$, as determined by one-way ANOVA and Tukey's test.

Crude fiber content of mango peel and pulp: Soluble dietary fibers present in fruits and vegetables are known to slow down gastric emptying by forming a viscous, gel-like matrix in the gastrointestinal tract. This altered environment can partially suppress the activity of digestive enzymes, thereby reducing the rate of macronutrient absorption. As a result, incorporating dietary fiber into the diet is believed to enhance satiety by decreasing the rate at which nutrients are absorbed, particularly fats [23]. Therefore, it is important to assess the crude fiber content in fruits and vegetables.

The results of the present study revealed that the mango peel contains a higher crude fiber content (15.66 ± 0.28%), compared to the mango pulp (4.66 ± 0.76%). A previous study conducted in India on three mango varieties, namely Alphonso,

Kesar and Totapuri, reported that the crude fiber content of peel ranged from 10.20 ± 0.08% to 10.91 ± 0.85% while that of pulp ranged from 0.32 ± 0.03% to 0.68 ± 0.03% [24]. A previous study conducted in Nigeria reported that the crude fiber content of peels of three mango varieties, Paparanda, Julie and Peter ranged from 13.79 ± 0.16% to 15.45 ± 0.08% [25]. Jayalaxmi *et al*. [26] reported that the crude fiber content of mango peel was 8.87%. According to a previous study conducted in Sri Lanka using five mango varieties, namely, Karthakolomban, Willard, Bettiamba, Malwana and Gira Amba, the crude fiber percentage of pulp ranged from 1.17 ± 0.05% – 3.16 ± 0.06% [27]. Findings from the previous studies, along with the results of the present study, suggest that the crude fiber percentage is consistently higher in mango peel compared to the pulp across various mango varieties. Therefore, mango peel, often discarded as waste, can be considered a significant contributor of dietary fiber and may be utilized in the development of fiber-rich functional foods or dietary supplements.

***In vitro* sun protection factor and photostability:** The effectiveness of sunscreen products in protecting the skin from ultraviolet (UV) radiation–induced damage is expressed as the sun protection factor (SPF). The determination of SPF helps explore their potential as skin-friendly UV-protectants, bridging research, dermatology and product innovation. The extract of peel exhibited a broad absorbance in the UV-B region (290-320 nm), suggesting its potential photo-protective properties.

According to the standard guidelines, sunscreen products can be classified into three types based on their SPF values [28]. Products with the SPF from 2 to less than 12, are considered ''minimal sun protection products. Those with an SPF from 12 to less than 30 are classified as ''moderate sun protection products'' while the products with an SPF 30 or higher are considered "high sun protection products". The SPF values of the peel and pulp extracts, calculated using the Mansur equation, are summarized in Table-3.

TABLE-3
SPF OF ETHANOL EXTRACTS OF MANGO PEEL, PULP AND REFERENCE SUNSCREEN

Sample	SPF
Peel extract	31.10 ± 1.18[a]
Pulp extract	2.00 ± 0.20[b]
Reference sunscreen	37.29 ± 2.19[c]

Note: Data are expressed as mean ± standard deviation (n = 3). Values with distinct superscript letters indicate significant differences at $p \leq 0.05$, as determined by one-way ANOVA and Tukey's test.

The results reveal that both the peel extract and reference sunscreen possess strong sun protective properties. In contrast, the SPF value of the pulp extract (2.00 ± 0.20) indicates that it exhibits minimal sun protective properties. To be effective in protecting skin against UV light, the photo-protective agent must be both heat-stable and photo-stable. Therefore, the UV absorbance of the peel extract was measured by exposing the sample to direct sunlight for 21 days to determine its photo-stability. The absorbance of the reference sample was also measured simultaneously. The calculated SPF values of the peel extract and reference sample are given in Table-4 and graphically depicted in Fig. 2.

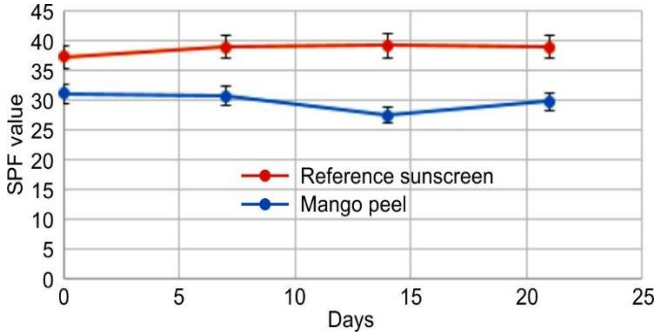

Fig. 2. Photostability comparison of the ethanolic extract of mango peel and the reference sunscreen

TABLE-4
SPF VALUES OF THE MANGO PEEL EXTRACT AND REFERENCE SUNSCREEN

Day	SPF of the peel sample	SPF of the reference sample
Initially	31.10 ± 1.18[a]	37.29 ± 2.19[b]
7th Day	30.79 ± 0.04[a]	38.93 ± 0.08[b]
14th Day	27.49 ± 0.38[a]	39.20 ± 0.05[b]
21st Day	29.85 ± 0.06[a]	39.01 ± 0.12[b]

Note: Data are presented as mean ± standard deviation (n = 3). Statistical analysis was conducted using one-way ANOVA followed by Tukey's test. No statistically significant differences were found between the values ($p > 0.05$).

The initial SPF of the peel extract was 31.10 ± 1.18, while the reference sunscreen showed a higher value of 37.29 ± 2.19. Over the 21 days, the SPF of the peel extract slightly fluctuated, showing values of 30.79 ± 0.04, 27.49 ± 0.38 and 29.85 ± 0.06 on the 7th, 14th and 21st days, respectively. In contrast, the reference sample maintained relatively stable SPF values of 38.93 ± 0.08, 39.20 ± 0.05 and 39.01 ± 0.12 over the same period. Despite numerical variations, statistical analysis indicated no significant difference ($p > 0.05$) in the SPF values of either sample throughout the 21-day exposure, indicating that both the peel extract and the commercial sunscreen exhibit good photostability under natural sunlight conditions. Thus, based on its photostability, future research could focus on incorporating mango peel extract into formulations as a sustainable and natural source of UV protection. However, comprehensive safety studies should be conducted before its use in commercial products.

GC/MS analysis of extract of mango peel: The volatile chemical compounds identified in TomEJC mango peel extract by GC/MS analysis are presented in Table-5.

A previous study conducted in China, reported the presence of 4-ethyl-phenol and 2,4-dimethylphenol in mango peel [29]. A study conducted in Egypt aimed to identify the volatile compounds present in the peels of 13 mango cultivars namely, Alfons, Ewaise, Baladi, Fagr, Misk, Fuss, Ket, Langary, Naomee, Sobaa El-set, Succari, Tomy and Zebda reported by GC/MS analysis [18]. Compound 2-furancarboxaldehde, 5-methyl was found in the peels of Succari, Ket, Langary, Fagr, Misk, Naomee, Sobaa el-set, Tomy, Baladi, Alfons mango cultivars, whereas benzene, methyl(1-methylethyl) was detected in the peels of Tomy, Ket and Langary mago cultivars while 1-octadecene was found in the peel of Succari mango cultivar, similar to its presence in TomEJC mango peel [18].

TABLE-5
IDENTIFIED VOLATILE CHEMICAL CONSTITUENTS IN MANGO PEEL EXTRACT

Compound	Retention time (min)
2-Furancarboxaldehyde	4.8635
Benzene, 1,3-*bis*(1,1-dimethylethyl)	12.1642
Docosane	15.3526
Phenol, 2,4-*bis*(1,1-dimethylethyl)	15.5643
Hentriacontane	15.8979
Diethyl Phthalate	16.6164
1-Octadecene	17.5851
Heptadecane	17.7134
1-Heptadecene	19.1633
Decane, 2-methyl	20.1063

Conclusion

The findings indicate that the ethanolic extract of the TomEJC mango peel contains significantly higher levels of total phenolic content (TPC), total flavonoid content (TFC) and crude fiber compared to the pulp. Specifically, the peel extract contained 17.69 ± 0.51 mg gallic acid equiv./g extract (TPC), 13.39 ± 0.43 mg quercetin equiv./g extract (TFC) and 15.66 ± 0.28% crude fiber. It was also rich in phytochemicals, exhibited stronger antioxidant activity (IC_{50} = 76.96 ± 5.11 µg/mL) and demonstrated a higher photoprotective potential (SPF = 31.10 ± 1.18) than the pulp. These results emphasize the promising potential of TomEJC mango peel, a byproduct of mango processing as a valuable source of bioactive compounds with antioxidant and photoprotective properties, supporting its application in herbal nutraceutical and cosmeceutical industries.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

DECLARATION OF AI-ASSISTED TECHNOLOGIES

During the preparation of this manuscript, the authors used an AI-assisted tool(s) to improve the language. The authors reviewed and edited the content and take full responsibility for the published work.

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