

Article

Utilization of Colored Extracts for the Formulation of Ecological Friendly Plant-Based Green Products

Shahid Adeel ¹, Maryam Habiba ², Shumaila Kiran ³, Sarosh Iqbal ³, Shazia Abrar ^{3,*} and Ch Moazzam Hassan ³

¹ Department of Chemistry, Government College University, Sir Syed Block, New Campus Jhang Road, Faisalabad 38000, Pakistan

² Minhaj University, Main Campus Hamdard Chowk Township, Lahore 54770, Pakistan

³ Department of Applied Chemistry, Government College University, Sir Syed Block, New Campus Jhang Road, Faisalabad 38000, Pakistan

* Correspondence: shaziaabrar@gcuf.edu.pk

Abstract: Green or sustainable cosmetics are products that contain natural ingredients obtained from renewable raw materials. Fruit peels represent a sustainable source of bioactive compounds. Polyphenols, e.g., flavonoids, have the ability to scavenge free radicals; thus they exhibit antioxidant activity. Recently, natural antioxidants have been in the limelight as being safe, effective, and versatile. In this study, antioxidant effects and the sun protection ability of apple (*Malus domestica*), banana (*Musa sapientum*), and orange (*Citrus reticulata*) peel extracts were evaluated in skincare formulations. The extraction of phenolic compounds was performed in three different solvents, i.e., ethanol, methanol, and acetone. Total phenolic contents, antioxidant activity, and sun protection factor were determined for the fruit peel extracts. The acetone extract of apple and ethanol extract of banana peels contained polyphenols, i.e., 24.3 ± 1.5 and 26.7 ± 0.6 mg GAE per gram of the extracts, respectively. These extracts showed DPPH radical scavenging activity and were incorporated into oil-in-water (O/W) cosmetic emulsions. All the formulated samples were found to be stable when subjected to centrifuging and thermal stress. Antioxidant activities of cream samples were above 80%, and the sun protection factor was above 15. The results have confirmed the applications of fruit peel waste in the formulation of photostable, antioxidant, and sun screen formulations. These creams would help to maintain skin health, protect it from UV radiation, and reduce the aging effect. Thus, fruit peel waste could present an ecofriendly and sustainable source of natural antioxidants for the personal care industry.

Keywords: natural antioxidants; antiaging; sun screening; phenolic compounds; cosmetic formulation



Citation: Adeel, S.; Habiba, M.; Kiran, S.; Iqbal, S.; Abrar, S.; Hassan, C.M. Utilization of Colored Extracts for the Formulation of Ecological Friendly Plant-Based Green Products. *Sustainability* **2022**, *14*, 11758. <https://doi.org/10.3390/su141811758>

Academic Editor: Abu Naser Md Ahsanul Haque

Received: 10 August 2022

Accepted: 14 September 2022

Published: 19 September 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Due to the green revolution, the utilization of natural ingredients in personal care products has extensively increased in recent decades [1]. Plant-based biochemicals show various unique characteristics, i.e., they are biodegradable, non-toxic, eco-friendly, and sustainable. Natural ingredients such as colorants have been studied for their application in the textile and food industries [2–4]. The cosmetic industry is one of the important fields where phytochemicals can be applied to obtain various health benefits [5]. Cosmetic products, such as creams, lotions, lipsticks, etc., are applied directly to external body parts for the purpose of skin cleansing and beautification. The use of synthetic chemicals in cosmetics may expose our body system to various harmful chemicals and toxic heavy metals. Therefore, the replacement of synthetic chemicals with plant-based natural ingredients helps to obtain safe, ecofriendly, and sustainable cosmetic products.

Fruit peels are the waste by-product of the fruit processing industry and have been studied as a sustainable potential source of various bioactive compounds. Polyphenols such as phenolic acids, flavonoids, anthocyanins, tannins, and stilbenes are organic compounds

responsible for the plant's defensive system for fighting various types of stresses owing to their strong therapeutic properties [6,7]. Fruit peels have been reported to contain a much higher concentration of plant acids compared to edible fruit flesh, thus exhibiting higher antioxidant potential [8,9]. Phenolic compounds can prevent oxidation reactions by scavenging the free radicals to form more stable phenoxy radicals, which results in a decrease in oxidative damage at the cellular level [10,11]. The important phenolic compounds present in some common fruit peels are caffeic acid, ferulic acid, sinapinic acid, coumaric acid, quercetin, epicatechin, etc. [12,13]. These compounds show several therapeutic properties, such as anti-inflammatory, antibacterial, antityrosinase, antiaging, antiallergic, anticarcinogenic, etc. [14–17]. Therefore, fruit peel extracts present an excellent sustainable source of natural compounds required for antiacne and antiaging, dermo protective skincare formulation, thus boosting overall skin quality. Caffeic acid and ferulic acid may help to alleviate the photosensitization and thus protect the skin from UV-induced photo-damaging reactions [18,19]. Thus, phenolics reduce the photoaging, pigmentation, and carcinogenic reactions in the skin [20,21]. The therapeutic properties of phenolic compounds in fruit peels of banana, apple, and orange can be utilized for the formulation of ecofriendly and multipurpose skincare cosmetics. The best way to achieve the benefits of these natural ingredients is to incorporate them into a stable system such as emulsions. Emulsions are active vehicles with a chemical composition suitable for skin. Emulsions provide stability to the natural extracts with enhanced permeability as compared to solutions and gels. The main components of creams are fatty alcohols/fatty acids, emollients, and moisturizers that can increase the absorption of the active ingredient into the lipid layer of the skin. The characterization of these formulations, especially the physical and chemical stability of the extracts in the formulation, is required to accomplish the desired efficacy of the product.

The main objective of the current research work was to determine polyphenol contents, antioxidant activity, and sun protection factor (SPF) of cosmetic formulations containing peel extracts of apple (*Malus Domestica*), banana (*Musa sapientum*), and orange (*Citrus reticulata*). The extraction of phenolic compounds was accomplished using solvents such as ethanol, methanol, and acetone. The total phenolic contents and antioxidant activities of all the extracts were measured using a DPPH assay and compared with a controlled set of experiments. The main objective was to incorporate the antioxidants from fruit peels into stable oil in water (O/W) type skin care products. The SPF factor was measured for the estimation of their UV-protecting ability. The physical and photostability of the formulations were determined. To the best of our knowledge, the utilization of fruit peel antioxidants for the formulation of multipurpose, stable skincare formulations has not been studied so far.

2. Materials and Methods

2.1. Materials and Reagent

All the solvents and reagents were of analytical grade. Deionized water, ethanol, methanol, and acetone were purchased from Pakistan Chemical Store, Jinnah colony, Faisalabad, Pakistan. All the reagents and chemicals, i.e., DPPH (2,2-diphenyl-1-picrylhydrazyl), Folin-Ciocalteu reagent, sodium carbonate, gallic acid, ascorbic acid, polawax, shea butter, EDTA, parabens, and stearic acid, were purchased from Sigma Aldrich.

The apple (*Malus domestica*), banana (*Musa*), and orange (*Citrus X sinensis*) were obtained from the local market. The fruits were peeled, and the peels were air dried, ground to a fine powder, and stored in an air-tight container for further use.

2.2. Preparation of Fruit Peels Extracts

The fruit peel extracts were prepared by following the method reported in the literature with slight modifications [22]. The fruit peel powder (25 g) of each sample was soaked in 500 mL of solvent (80% and 100% acetone, ethanol, methanol) and incubated at room temperature overnight. It was stirred on a hot plate using a magnetic stirrer at 200–250 rpm at 35 °C for 3 h, filtered using Whatman No. 1 filter paper and then centrifuged at 6000 rpm

for 10 min at -4°C . The supernatant was filtered, separated, and then concentrated using a rotary evaporator. The extracts were dried up to 40°C and stored in the refrigerator, thus preserving the phenolic compounds present in the extracts.

2.3. Determination of Total Phenolic Content (TPC)

Total phenolic content (TPC) was determined by following the spectrophotometric method [23]. A double-beam UV-VIS spectrophotometer LX212DS was used. It has a wavelength range of 190–1100 nm, with a tungsten lamp as a source of visible light. The absorbance of the resulting mixture was measured at 750 nm using distilled water as the blank. The calibration curve was prepared using gallic acid as standard with a concentration range of (25–500 mg/mL). Total phenolic content was measured as mg gallic acid equivalent per gram of the extract (mg of GA/g of extract).

2.4. Determination of DPPH Radical Scavenging Activity

Antioxidant activity was determined in terms of DPPH radical scavenging activity [24]. The extract was prepared (1 mg/mL), and 3 mL was added to 3 mL of 0.1 mM DPPH solution and incubated in the dark for 20 min. The absorbance was measured at 518 nm using a double-beam UV/VIS spectrophotometer. Ethanol was used as the blank, and ethanolic DPPH as the control. Ascorbic acid was used as standard. The results were expressed as % age DPPH radical scavenging activity using the formula:

$$\% \text{ age scavenging} = \frac{A_c - A_e}{A_c} \times 100$$

where A_c is the absorbance of the control without the sample, and A_e is the absorbance of the solution with the sample.

2.5. Development of O/W Emulsion with Fruit Peel Extracts

Oil-in-water (O/W) emulsions with dried extracts of fruit peel were prepared. A control base without extract was also formulated with oil and water phases, as mentioned in Table 1. The oil phase consists of petrolatum, shea butter, stearic acid, and almond oil, and was heated up to 70°C and then added to the preheated (75°C) water phase, along with preservatives and emulsifier (polawax). The mixture was continuously stirred vigorously for 15 min and then cooled down at room temperature. In the next step, fruit peel extracts were added (4.0% to the cooled emulsion). A control cream base was prepared without the addition of fruit peel extracts.

Table 1. Composition of formulations.

Ingredients	Apple	Banana	Orange	Control Base
Water	Q.S.	Q.S.	Q.S.	Q.S.
EDTA	0.05%	0.05%	0.05%	0.05%
Glycerine	2.5%	2.5%	2.5%	2.5%
Polawax	5%	5%	5%	5%
Shea butter	1%	1%	1%	1%
Stearic acid	0.3%	0.3%	0.3%	0.3%
Petrolatum	1%	1%	1%	1%
Extract	4%	4%	4%	0%
Almond Oil	1%	1%	1%	1%
Perfume	1%	1%	1%	1%
Parabens	0.2%	0.2%	0.2%	0.2%

2.6. Basic Characterization of Formulations

The prepared samples of emulsions were evaluated for basic parameters such as physical appearance, homogeneity, stability, and pH.

2.6.1. pH and Stability Testing

The pH of all the cream samples was measured immediately after formulation and after an interval of 30 days using HANNA HI-2211 benchtop pH meter.

The stability testing was performed in triplicate by measuring the accelerated stability, centrifuge test, freezing, and thawing cycles. The accelerated stability was measured at three different temperatures (8 °C, 25 °C, and 40 °C) with a 30-day interval for 90 days. All the samples were subjected to the freezing and thawing cycle by placing them in the freezer at a temperature of −5 °C for one day and then in an oven at 40 °C for the next day, completing the six consecutive cycles for 12 days. All the samples were centrifuged at 3000 rpm for 10 min.

2.6.2. Spreadability

Spreadability was measured by the method reported in the literature. Each cream sample (1 g) was placed evenly on a circular glass disc, and the disc was covered with glass and a weight (100, 200, 300, 400 in grams) was placed on it for 5 min. The distance covered by the sample was measured, and the spreadability was calculated. It was expressed in millimeters of increased diameter. The spreadability factor (Sf) was calculated by the following equation:

$$Sf = A/W$$

2.6.3. Sun Protection Factor

The sun protection factor was determined using a double-beam UV-VIS spectrophotometer. The sample (1 g) was diluted with 100 mL of ethanol and sonicated for 10 min. It was filtered, and the absorbance of the filtrate was measured from 290 to 320 nm at an interval of 5 nm. The results were calculated with the help of the normalized Mansur equation [25].

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

In this equation: CF—correction factor (CF = 10); *EE* (*l*)—erythemal effect spectrum; *I* (*l*)—solar intensity spectrum; *Abs* (*l*)—absorbance of sunscreen product.

2.6.4. Photostability

The photostability was measured by the reported method [26]. The sample (1 g) was applied evenly on a glass disc and placed under a UV light source from a Philip lamp at 254 nm (30 W, 100% emission) for 2 h. The SPF of the sample was measured before and after the exposure. It was expressed as the percentage and calculated by using the following equation.

$$\text{Photostability} = \frac{\text{SPF of cream}}{\text{SPF of UV irradiated cream}} \times 100$$

2.7. Antioxidant Activity of Cream

The cream samples (1 g) were diluted with 100 mL of ethanol and sonicated for 10 min. The mixture (10 mL) was further diluted with 100 mL of ethanol. The liquid extract, i.e., 3 mL (1 mg/mL), was added to 3 mL of 0.1 mM DPPH solution and incubated in the dark for 20 min. The absorbance was measured at 518 nm using a UV-VIS Spectrophotometer. Ethanol was used as blank and ethanolic DPPH as control. The result was expressed as %-age DPPH radical scavenging activity using the formula:

$$\% \text{ age scavenging} = \frac{A_c - A_e}{A_c} \times 100$$

where A_c is the absorbance of the control without the sample, and A_e is the absorbance of the solution with the sample.

2.8. Statistical Analysis

All the measurements were performed in triplicates for statistical analysis, i.e., means, standard deviation (S.D.), and standard error (S.E.), was performed using IBM SPSS Statistics (version 26.0) software. It was installed from Department of Information Technology, Government College University Faisalabad, Pakistan.

3. Results and Discussion

3.1. Extraction and Determination of Total Phenolic Contents (TPC)

The extracts of fruit peels were prepared in different solvents, i.e., ethanol, methanol, and acetone. The concentration of plant phenolics varies according to the nature of the solvent and the method used for extraction. The Folin–Ciocalteu (F-C) reagent is generally used for the determination of phenolic contents in the extracts. This F-C can also react with other non-phenolic components, i.e., folic acid, ascorbic acid, thiamine, nucleic acids, ascorbic acid, and some metal ions [27]. Since the most abundant antioxidants present in the extracts are phenolics, the values obtained by the F-C reagent are due to the phenolic contents. Gallic acid was used as standard, and a calibration curve was prepared using different concentrations (15, 30, 50, 100, 200 mg/L) of gallic acid. The linear relationship between the concentrations of gallic acid and absorbance is shown as a standard curve in Figure 1.

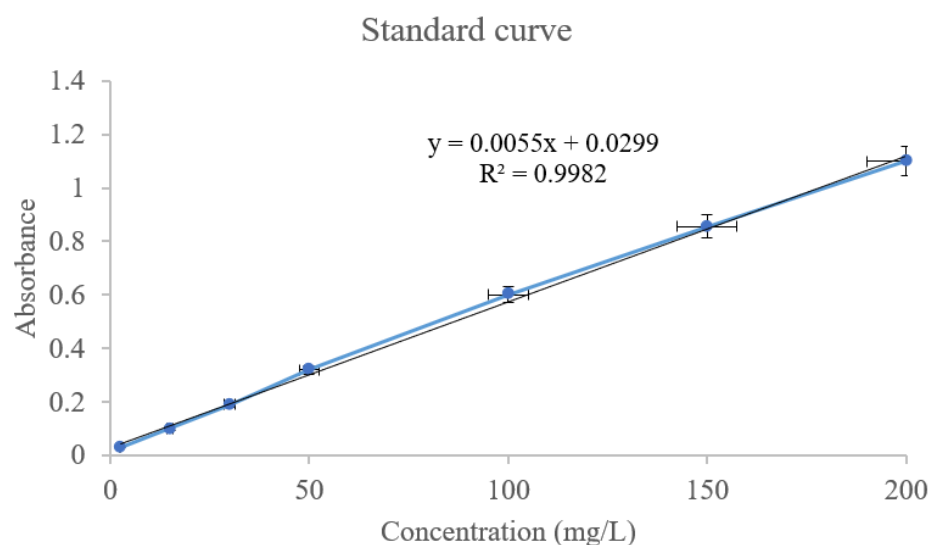


Figure 1. Linear curve of standard gallic acid (mg/L).

The concentration of total phenolic contents (TPC) of apple, orange, and banana peel extracts was expressed in mg of gallic acid equivalent per gram of the extract (mg GAE/g). The concentration of phenolic compounds in apple peels ranges from 5.3 ± 0.5 to 24.3 ± 1.5 mg GAE/g, as shown in Figure 2. Quantitative analysis of phenolic contents from different apple varieties has confirmed the highest level of phenolics, i.e., catechins, flavonol glycosides, and rutin, are in apple peels compared to pulp [28]. Phenolic compounds are mainly responsible for the antioxidant activity of apple peels. The results showed maximum TPC in pure acetone while the minimum was found in pure ethanol. The acetone can better penetrate the plant cells and extract the phenolics efficiently [29]. The values of TPC were comparable to the values reported [16].

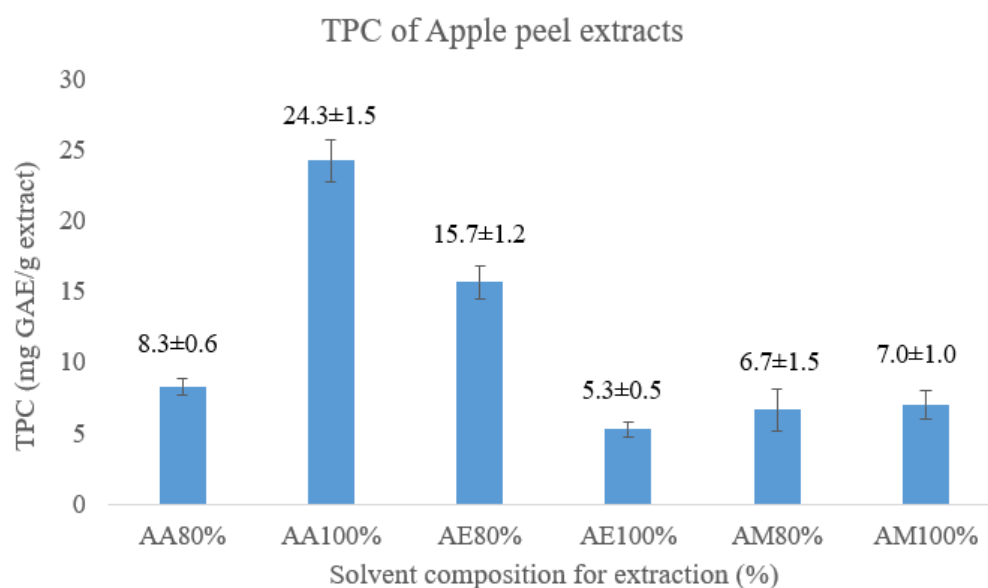


Figure 2. Total phenolic content (mg GAE/g of extract) in apple peel. (AA = Apple Acetone, AE = Apple Ethanol, AM = Apple Methanol).

Banana peels make a significant contribution to agro-industrial waste, which can not be utilized efficiently. The best way to consume these is to extract their phenolic contents for use in the food or cosmetic industries. In banana peel extract, TPC ranged from 21.3 ± 1.5 to 26.7 ± 0.6 mg GAE/g, as shown in Figure 3. Maximum phenolics were found in pure ethanol followed by pure acetone, while minimum phenolics were in 80% methanol. The literature has confirmed maximum phenolic contents in the banana peels as compared to the pulp and galocatechin was most abundant among other polyphenols [30]. The concentration of phenolics in banana peels has been reported in the literature [7]. Orange peels showed TPC values from 11.7 ± 1.5 to 29.0 ± 1.0 mg GAE/g, as shown in Figure 4. A high level of TPC was found in acetone (100%), followed by 80% methanol, while minimum phenolics were depicted in pure ethanol and pure methanol.

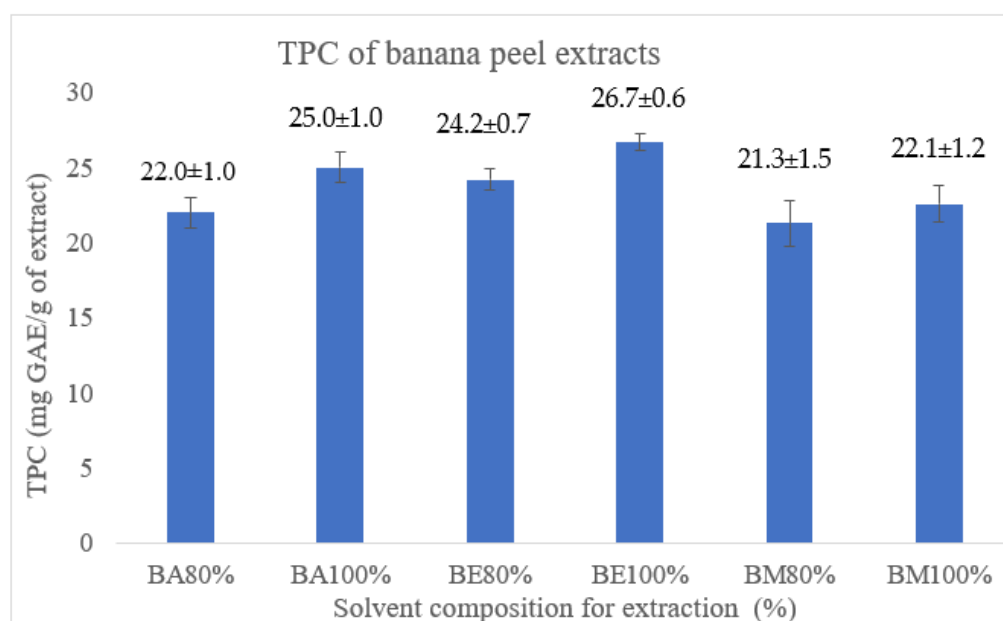


Figure 3. Total phenolic content (mg GAE/g of extract) in banana peel. (BA = Banana Acetone, BE = Banana Ethanol, BM = Banana Methanol).

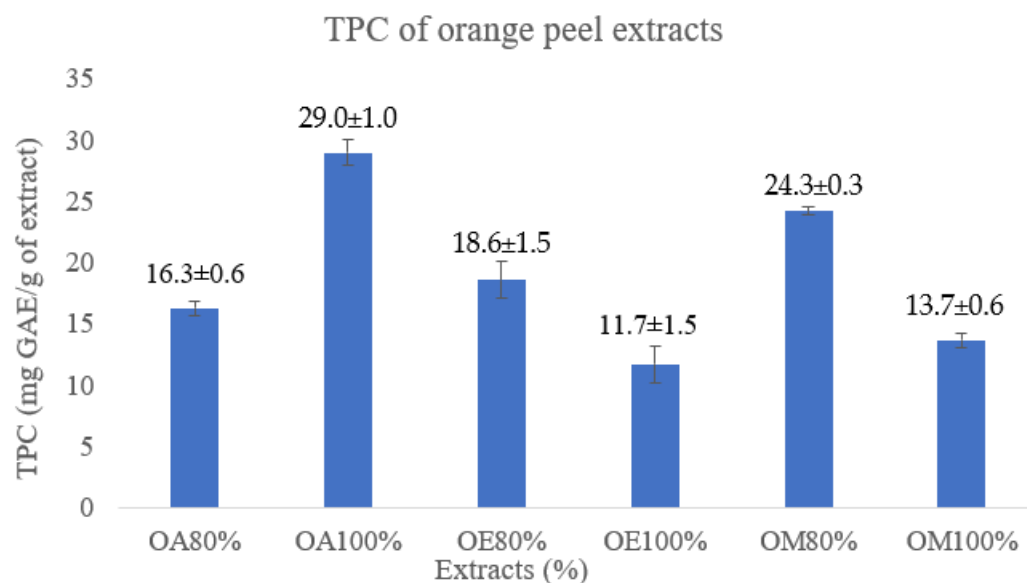


Figure 4. Total phenolic content (mg GAE/g of extract) in orange peel. (OA = Orange Acetone, OE = Orange Ethanol, OM = Orange Methanol).

The concentration of TPC in different extracts was influenced by the nature of the solvent. Varying the solvent polarity changed the total phenolic content expressing different solubility of phenols in the different solvent environments. The addition of water decreased the total phenolic content, which suggests that water may solubilize other compounds such as carbohydrates leading to lower TPC values [31]. One-hundred percent acetone was found more appropriate under our experimental conditions to prepare apple and orange peel extracts, while 100% ethanol yielded higher TPC in banana peel extract. Consequently, acetone extracts of fruit peels were preferred for further study.

3.2. Antioxidant Activity

Antioxidant activity is related to the concentration of phenolics in fruit peel extracts [32]. It was measured in terms of DPPH radical scavenging activity. All the extracts showed different radical scavenging patterns, as shown in Figure 5. Antioxidant activity of peel extracts ranged from 60.2% to 75.6% free radical scavenging, with apple peel extracts exhibiting the best antioxidant activity in terms of DPPH radical scavenging. It has been investigated that apple peels showed higher antioxidant potential than apple flesh [33]. These peel extracts also exhibited antimicrobial and anticancer activities. The phenolic extracts of peels can represent a valuable source of antioxidants for reducing photooxidation. The antioxidant activity of standard ascorbic acid as a function of increasing concentration is shown in Figure 6. One of the important extrinsic factors that induce skin aging is the oxidative stress caused by UV radiation [34]. In prolonged exposure to sunlight, free radicals are produced in the skin. These reactive oxygen species (ROS) not only cause the oxidation of biomolecules but also damage the dermal connective tissues, ultimately affecting the skin elasticity that leads to aging effects [35]. Antioxidants scavenge free radicals and hence minimize oxidative stress [36]. The free radical scavenging mechanism can be utilized to formulate the antiaging formulation by incorporating the natural extracts of phenolic compounds. Hence the free radical scavenging activities of fruit peel extracts make them a potent ingredient for skincare cosmetic formulations.

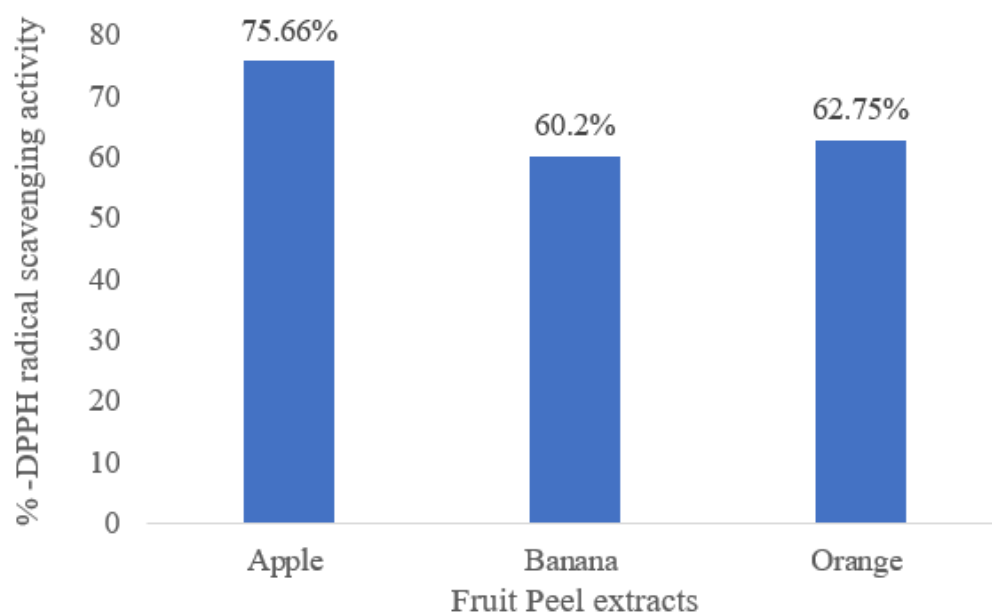


Figure 5. DPPH radical scavenging activity of fruit peel extracts.

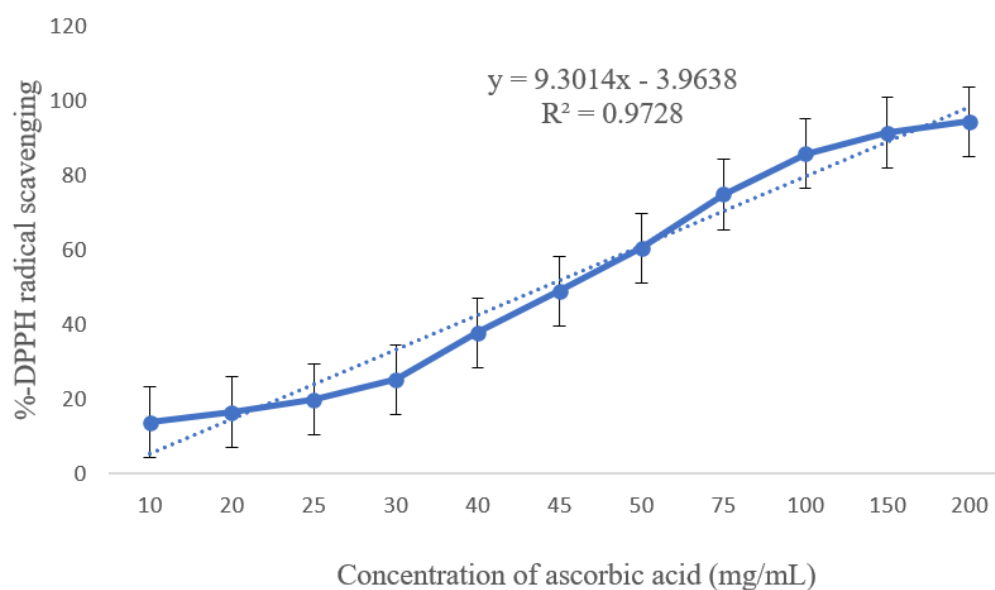


Figure 6. DPPH radical scavenging activity of standard ascorbic acid.

The antioxidant activity of all the formulations has been presented in Table 2. This determines the stability and efficacy of extracts in terms of their antioxidant activity after being incorporated into emulsions. The formulations showed significant DPPH radical scavenging activities, which depict that these fruit peel extracts are a stable source of antioxidants, and they maintained their effect even in cosmetic emulsions. Furthermore, the antioxidant activity of the cream formulations is directly related to the antioxidant potential of the extract. Hence, these fruit peel extracts are consistent enough to act as a source of antioxidants in cosmetic formulations. To the best of our knowledge, no previous studies have reported the utilization of fruit peel extracts for the formulation of stable skincare formulations.

Table 2. SPF, photostability, and antioxidant activity of cream base and formulations with fruit peel extracts (ACR—cream with apple peel extract; BCR—cream with banana peel extract; OCR—cream with orange peel extract).

Sample	Extract	Color	SPF	Photostability	Antioxidant Activity
CRB	None	White	4.0 ± 0.2	-	None
ACR	Apple	Cream	20.0 ± 0.4	95%	88.0%
BCR	Banana	Gold brown	19.0 ± 0.2	98%	87.2%
OCR	Orange	Orange	18.3 ± 0.1	97%	80.0%

3.3. Incorporation of Extracts into Emulsion

Emulsions are vehicles that enhance the absorption of both hydrophilic and lipophilic active ingredients into the cutaneous layer of skin. Creams are semisolid emulsions consisting of water and oil phases homogenized by using emulsifiers. The delivery is influenced by the interaction between the active ingredients, the vehicle, and the skin. Either the active ingredients are incorporated in the dispersed phase or continuous phase of the emulsion, its absorption is enhanced by increasing interaction with the skin epidermis [37]. In the current study, oil-in-water (O/W) emulsions were prepared as the vehicle for delivering antioxidants. Moreover, in oil-in-water type emulsion (O/W), water as the external phase increases the hydration level of the stratum corneum, thus increasing the absorption of hydrophilic compounds. Extracts rich in antioxidants were incorporated into the emulsions for their delivery to the skin epidermis. In order to reduce the reactive oxygen species, natural antioxidants must be able to permeate and penetrate through the strum corneum and reach the deeper layers of the skin. The emulsion (O/W) was prepared using the ingredients listed in Table 1. The peel extracts were added to the cream base at a concentration of 4%. All the extracts were colored, which imparted a beautiful appearance to the emulsions, which is an important aspect of cosmetic products. The visually attractive products are more liked by consumers. ACR (cream with apple peel extract) was light yellow, BCR (cream with banana peel extract) appeared golden brown, and OCR (orange peel extract) was light orange. Fruit peel extracts were completely homogenous in formulations without any aggregation or lumps. The basic parameters of the formulations are expressed in the above Table 2.

3.4. Emulsion Stability Studies

To ensure the quality, efficacy, and safety of the products, it is essential to perform stability studies of cosmetic formulations. Such studies involve the monitoring of the physicochemical characterization of the formulations throughout the study period. pH is an important characteristic of the formulation that determines the effectiveness of the ingredients and stability of the formulation. The normal skin pH range is 4.5–6.5, and cosmetic formulations that have pH in this range are considered safe for the skin [38]. A change in pH represents the change in the efficacy of the product. The pH of all the formulations and cream bases was determined immediately after their manufacturing and then after 30 days. There was no significant change in pH observed throughout the study period. After the centrifuge testing, the pH of all the samples remained unchanged, as shown in Table 3, which confirmed the stability of the product.

The stability of the emulsions containing extracts was assessed by subjecting them to thermal stress, photo radiation, and centrifugation. It was found that all the samples of creams were stable with no phase separation and liquefaction. There was no change in the physical state, color, and pH after the stability testing. During the centrifuge test, the samples were subjected to a change in gravity conditions through the differential density of the oil and water phases. However, no physical instability was observed in terms of phase change after the centrifugation.

Table 3. pH of the cream formulation.

Sample	pH (0 Time)	pH (30 Days)	pH (After Centrifuge)
CRB	5.07 ± 0.1	5.03 ± 0.2	5.06 ± 0.1
ACR	5.45 ± 0.3	5.41 ± 0.1	5.45 ± 0.1
BCR	5.53 ± 0.1	5.52 ± 0.2	5.53 ± 0.3
OCR	4.89 ± 0.2	4.85 ± 0.4	4.87 ± 0.1

(CRB: Cream base; ACR: Apple Cream; BCR: Banana Cream; OCR: Orange cream).

3.5. Characterization of the Emulsions

3.5.1. Spreadability

The term spreadability of the emulsion is used to express the extent of ease by which an emulsion is applied to the skin. It is an important characteristic as it determines the even distribution of the active ingredients in the emulsion. Different factors can affect the spreadability of the emulsion, i.e., the temperature, composition of the emulsion, storage conditions, and viscosity of the emulsion. In order to see the difference, the spreadability of the emulsion prepared with extracts and that of the control base were compared. Under the similar condition of temperature, there was no change in the spreadability of different emulsion samples except one, which contained orange peel extracts. A good spreadability value defines the distribution and enhances the absorption of active ingredients in the skin. The values of the spreadability of the formulations samples (ACR, BCR, OCR) are presented in Figure 7. There was a linear increase in the spreadability of the sample with the increase in applied weight. All the samples showed good spreadability values. In the case of cream formulated with orange peel extract, the spreadability increased significantly as compared to other cream samples. Orange peel extracts contain anthocyanins, in addition to other flavonoids [39]. Due to their increased interaction of anthocyanins with the water phase of the O/W type emulsion, this cream sample has low viscosity and, thus, higher spreadability than other samples.

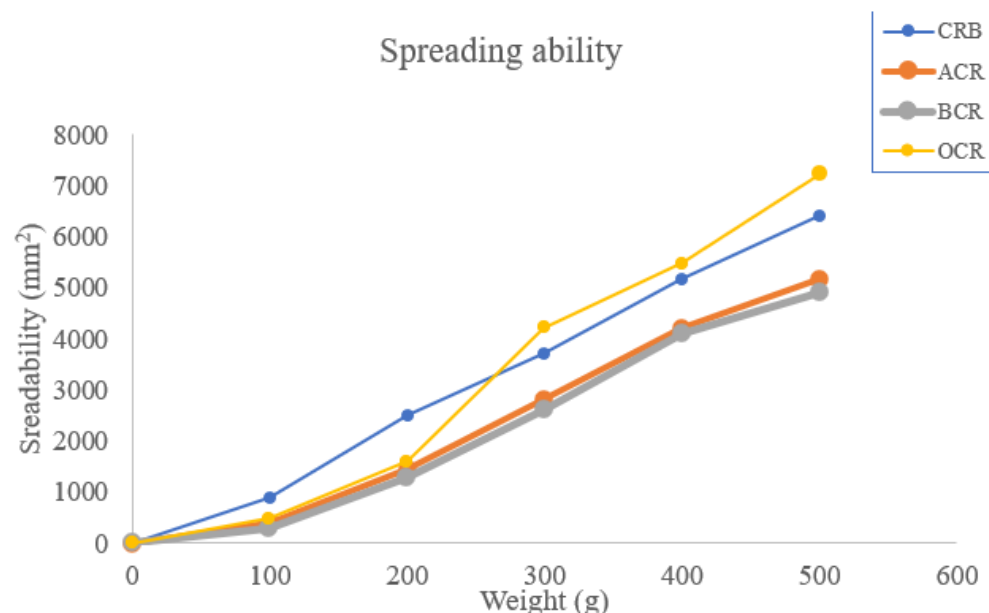


Figure 7. Spreadability of cream base (CRB) and formulations containing fruit peel extracts (ACR—cream with apple peel extract; BCR—cream with banana peel extract; OCR—cream with orange peel extract).

3.5.2. Sun Protection Factor (SPF)

Sun protection factor (SPF) is a measure of the efficiency of the sun screening formulation to absorb ultraviolet radiation from the sun, thus preventing the skin from UV-induced damage and sunburn. SPF is determined quantitatively by measuring the absorbance of UV radiation by the cosmetic emulsion, between 290 and 400 nm. It gives an estimate of the effectiveness of the sunscreen formulation. The higher the value of SPF, the higher will be the effect of the formulation against UV radiation. The results of the sun protection factor (SPF) of all the formulated samples and cream bases are given in Table 2. SPF is an important parameter for predicting the sunscreen ability of a cosmetic product. SPF above 15 is considered sufficient to prevent the incidence of skin cancer caused by UV radiation [40]. There are different factors that can affect the SPF value, such as the solvent, pH, the type of emulsion and composition of emulsion, and the interaction of the active ingredient with the skin. Other components of the emulsion can also interfere by absorbing UV radiation. For maximum efficacy of the extract, it must be uniformly spread on the skin as a thin film and remain close to the surface of the skin. Plant polyphenols exhibit antioxidant activity along with the absorption of UV radiation. These can be used as active ingredients in sun screening formulation. All the prepared samples showed an SPF above 15 with 4% extract. Hence these fruit peel extracts are a natural approach to required sun protection. It has been recommended by the Food and Drug Administration (FDA) that for getting appropriate UV-protection or SPF value, it is important to precisely apply the amount of sun protection vehicle (2.0 mg/cm^2) on the skin [41].

3.5.3. Photostability

In order to produce the desired effects, the antioxidants must remain on the skin without any degradation or change in chemical structure. Ultraviolet radiation of high intensity has the ability to degrade the active agents in cosmetic formulations, which could result in a decrease in their activity. For their optimum efficacy, the sun screening agents must remain stable during the period of exposure to sunlight. Therefore, a study of the photostability of the cosmetic product is very important. Many sunscreens, upon interaction with UV radiation, degrade and fail to protect the skin [42]. Further, the determination of photostability is important as it defines the UV-protection capacity of the sun screening formulations. It was found that all the formulations (ACR, BCR, and OCR) of fruit peel extracts were more than 95% photostable when irradiated with UV light, as shown in Table 2. Photostability makes the fruit peel extracts a reliable natural choice for sun screening formulations. These formulations being highly photostable, safe, and effective, are far better than various commercial sunscreen agents.

4. Conclusions

Fruit peels represent a valuable source of important phenolic compounds that are wasted away as useless material of the food industry. The current work found that acetone extract of apple and orange peels and ethanol extract of banana peels contain phenolic contents, i.e., 24.3 ± 1.5 , 29.0 ± 1.0 , and $26.7 \pm 0.6 \text{ mg GAE}$, respectively. These fruit peel extracts also showed significant antioxidant activity. The apple peels showed higher antioxidant potential, i.e., 75.6%, when compared with standard ascorbic acid. These extracts were successfully incorporated into (O/W) emulsions at a concentration of 4% and were stable under thermal stress, UV radiation, and centrifugation. The pH of the cream samples ranges from 4.89 ± 0.2 to 5.53 ± 0.1 . All the samples showed no change in their texture and pH throughout the study period. The formulated creams exhibited high sun protection factor (SPF), i.e., above 15. Since the creams samples were photostable, these can be applied to the skin when exposed to sunlight and to reduce skin aging effects. Fruit peels are abundantly available as a byproduct of the food industry; their utilization is useful for waste management. Their consumption will provide a cost-effective, ecofriendly, and sustainable alternative to synthetic antioxidants for the skincare and cosmetic industry.

Author Contributions: Data curation, C.M.H.; Formal analysis, M.H.; Investigation, S.K.; Methodology, S.I.; Supervision, S.A. (Shazia Abrar); Writing—review & editing, S.A. (Shahid Adeel). All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interests.

References

- Goyal, N.; Jerold, F. Biocosmetics: Technological advances and future outlook. *Environ. Sci. Pollut. Res.* **2021**. [CrossRef] [PubMed]
- Habib, N.; Akram, W.; Adeel, S.; Amin, N.; Hosseinneshad, M.; Haq, E.U. Environmental-friendly extraction of Peepal (*Ficus Religiosa*) bark-based reddish brown tannin natural dye for silk coloration. *Environ. Sci. Pollut. Res.* **2022**. [CrossRef] [PubMed]
- Hussaan, M.; Iqbal, N.; Adeel, S.; Azeem, M.; Tariq Javed, M.; Raza, A. Microwave-assisted enhancement of milkweed (*Calotropis procera* L.) leaves as an eco-friendly source of natural colorants for textile. *Environ. Sci. Pollut. Res.* **2017**, *24*, 5089–5094. [CrossRef] [PubMed]
- Kaderides, K.; Kyriakoudi, A.; Mourtzinou, I.; Goula, A.M. Potential of pomegranate peel extract as a natural additive in foods. *Trends Food Sci. Technol.* **2021**, *115*, 380–390. [CrossRef]
- Karray, A.; Krayem, N.; Saad, H.B.; Sayari, A. Spirulina platensis, Punica granatum peel, and moringa leaves extracts in cosmetic formulations: An integrated approach of in vitro biological activities and acceptability studies. *Environ. Sci. Pollut. Res.* **2021**, *28*, 8802–8811. [CrossRef]
- Choi, D.-Y.; Lee, Y.-J.; Hong, J.T.; Lee, H.-J. Antioxidant properties of natural polyphenols and their therapeutic potentials for Alzheimer's disease. *Brain Res. Bull.* **2012**, *87*, 144–153. [CrossRef]
- Mileo, A.M.; Nisticò, P.; Miccadei, S. Polyphenols: Immunomodulatory and Therapeutic Implication in Colorectal Cancer. *Front. Immunol.* **2019**, *10*, 729. [CrossRef]
- Ajila, C.M.; Naidu, K.A.; Bhat, S.G.; Rao, U.J.S.P. Bioactive compounds and antioxidant potential of mango peel extract. *Food Chem.* **2007**, *105*, 982–988. [CrossRef]
- Singh, B.; Singh, J.P.; Kaur, A.; Singh, N. Phenolic composition, antioxidant potential and health benefits of citrus peel. *Food Res. Int.* **2020**, *132*, 109114. [CrossRef]
- Aseervatham, G.S.B.; Sivasudha, T.; Jeyadevi, R.; Arul Ananth, D. Environmental factors and unhealthy lifestyle influence oxidative stress in humans—An overview. *Environ. Sci. Pollut. Res.* **2013**, *20*, 4356–4369. [CrossRef]
- Mathew, S.; Abraham, T.E.; Zakaria, Z.A. Reactivity of phenolic compounds towards free radicals under in vitro conditions. *J. Food Sci. Technol.* **2015**, *52*, 5790–5798. [CrossRef] [PubMed]
- Vu, H.T.; Scarlett, C.J.; Vuong, Q.V. Phenolic compounds within banana peel and their potential uses: A review. *J. Funct. Foods* **2018**, *40*, 238–248. [CrossRef]
- Lee, K.H.; Cho, J.-Y.; Lee, H.J.; Park, K.Y.; Ma, Y.-K.; Lee, S.-H.; Cho, J.A.; Kim, W.-S.; Park, K.-H.; Moon, J.-H. Isolation and identification of phenolic compounds from an Asian pear (*Pyrus pyrifolia* Nakai) fruit peel. *Food Sci. Biotechnol.* **2011**, *20*, 1539–1545. [CrossRef]
- Bouarab-Chibane, L.; Forquet, V.; Lantéri, P.; Clément, Y.; Léonard-Akkari, L.; Oulahal, N.; Degraeve, P.; Bordes, C. Antibacterial Properties of Polyphenols: Characterization and QSAR (Quantitative Structure–Activity Relationship) Models. *Front. Microbiol.* **2019**, *10*, 829. [CrossRef] [PubMed]
- Kazłowska, K.; Hsu, T.; Hou, C.-C.; Yang, W.-C.; Tsai, G.-J. Anti-inflammatory properties of phenolic compounds and crude extract from *Porphyra dentata*. *J. Ethnopharmacol.* **2010**, *128*, 123–130. [CrossRef] [PubMed]
- Nagendra Prasad, K.; Yang, B.; Yang, S.; Chen, Y.; Zhao, M.; Ashraf, M.; Jiang, Y. Identification of phenolic compounds and appraisal of antioxidant and antityrosinase activities from litchi (*Litchi sinensis* Sonn.) seeds. *Food Chem.* **2009**, *116*, 1–7. [CrossRef]
- Simic, M.G.; Jovanovic, S.V. Inactivation of Oxygen Radicals by Dietary Phenolic Compounds in Anticarcinogenesis. In *Food Phytochemicals for Cancer Prevention II*; ACS Symposium Series; American Chemical Society: Washington, DC, USA, 1994; Volume 547, pp. 20–32.
- González-Montelongo, R.; Lobo, G.; Gonzalez, M. Antioxidant activity in banana peel extracts: Testing extraction conditions and related bioactive compounds. *Food Chem.* **2010**, *119*, 1030–1039. [CrossRef]
- Correia, P.; Araújo, P.; Ribeiro, C.; Oliveira, H.; Pereira, A.R.; Mateus, N.; de Freitas, V.; Brás, N.F.; Gameiro, P.; Coelho, P.; et al. Anthocyanin-Related Pigments: Natural Allies for Skin Health Maintenance and Protection. *Antioxidants* **2021**, *10*, 1038. [CrossRef]
- Hubner, A.; Sobreira, F.; Vetore Neto, A.; Pinto, C.A.S.d.O.; Dario, M.F.; Díaz, I.E.C.; Lourenço, F.R.; Rosado, C.; Baby, A.R.; Bacchi, E.M. The Synergistic Behavior of Antioxidant Phenolic Compounds Obtained from Winemaking Waste's Valorization, Increased the Efficacy of a Sunscreen System. *Antioxidants* **2019**, *8*, 530. [CrossRef]

21. Hano, C.; Tungmunnithum, D. Plant Polyphenols, More than Just Simple Natural Antioxidants: Oxidative Stress, Aging and Age-Related Diseases. *Medicines* **2020**, *7*, 26. [\[CrossRef\]](#)
22. Pothitirat, W.; Chomnawang, M.T.; Supabphol, R.; Gritsanapan, W. Free radical scavenging and anti-acne activities of mangosteen fruit rind extracts prepared by different extraction methods. *Pharm. Biol.* **2010**, *48*, 182–186. [\[CrossRef\]](#) [\[PubMed\]](#)
23. Derakhshan, Z.; Ferrante, M.; Tadi, M.; Ansari, F.; Heydari, A.; Hosseini, M.S.; Conti, G.O.; Sadrabad, E.K. Antioxidant activity and total phenolic content of ethanolic extract of pomegranate peels, juice and seeds. *Food Chem. Toxicol.* **2018**, *114*, 108–111. [\[CrossRef\]](#) [\[PubMed\]](#)
24. Bandonienè, D.; Murkovic, M.; Pfannhauser, W.; Venskutonis, P.; Gruzdienè, D. Detection and activity evaluation of radical scavenging compounds by using DPPH free radical and on-line HPLC-DPPH methods. *Eur. Food Res. Technol.* **2002**, *214*, 143–147. [\[CrossRef\]](#)
25. Sharma, T.; Tyagi, V.; Bansal, M. Determination of sun protection factor of vegetable and fruit extracts using UV-Visible spectroscopy: A green approach. *Sustain. Chem. Pharm.* **2020**, *18*, 100347. [\[CrossRef\]](#)
26. Jarzycka, A.; Lewińska, A.; Gancarz, R.; Wilk, K.A. Assessment of extracts of *Helichrysum arenarium*, *Crataegus monogyna*, *Sambucus nigra* in photoprotective UVA and UVB; photostability in cosmetic emulsions. *J. Photochem. Photobiol. B* **2013**, *128*, 50–57. [\[CrossRef\]](#) [\[PubMed\]](#)
27. Everette, J.D.; Bryant, Q.M.; Green, A.M.; Abbey, Y.A.; Wangila, G.W.; Walker, R.B. Thorough study of reactivity of various compound classes toward the Folin–Ciocalteu reagent. *J. Agric. Food Chem.* **2010**, *58*, 8139–8144. [\[CrossRef\]](#)
28. Escarpa, A.; González, M.C. High-performance liquid chromatography with diode-array detection for the determination of phenolic compounds in peel and pulp from different apple varieties. *J. Chromatogr. A* **1998**, *823*, 331–337. [\[CrossRef\]](#)
29. Alberti, A.; Zielinski, A.A.F.; Zardo, D.M.; Demiate, I.M.; Nogueira, A.; Mafra, L.I. Optimisation of the extraction of phenolic compounds from apples using response surface methodology. *Food Chem.* **2014**, *149*, 151–158. [\[CrossRef\]](#)
30. Tongkaew, P.; Tohraman, A.; Bungaramphai, R.; Mitrpant, C.; Aydin, E. Kluai Hin (*Musa sapientum* Linn.) peel as a source of functional polyphenols identified by HPLC-ESI-QTOF-MS and its potential antidiabetic function. *Sci. Rep.* **2022**, *12*, 4145. [\[CrossRef\]](#)
31. Abozed, S.S.; El-kalyoubi, M.; Abdelrashid, A.; Salama, M.F. Total phenolic contents and antioxidant activities of various solvent extracts from whole wheat and bran. *Ann. Agric. Sci.* **2014**, *59*, 63–67. [\[CrossRef\]](#)
32. Agatonovic-Kustrin, S.; Kustrin, E.; Morton, D.W. Phenolic acids contribution to antioxidant activities and comparative assessment of phenolic content in mango pulp and peel. *S. Afr. J. Bot.* **2018**, *116*, 158–163. [\[CrossRef\]](#)
33. Wolfe, K.; Wu, X.; Liu, R.H. Antioxidant Activity of Apple Peels. *J. Agric. Food Chem.* **2003**, *51*, 609–614. [\[CrossRef\]](#)
34. de Jager, T.L.; Cockrell, A.E.; Du Plessis, S.S. Ultraviolet Light Induced Generation of Reactive Oxygen Species. *Adv. Exp. Med. Biol.* **2017**, *996*, 15–23. [\[CrossRef\]](#) [\[PubMed\]](#)
35. Rinnerthaler, M.; Bischof, J.; Streubel, M.K.; Trost, A.; Richter, K. Oxidative stress in aging human skin. *Biomolecules* **2015**, *5*, 545–589. [\[CrossRef\]](#)
36. Birben, E.; Sahiner, U.M.; Sackesen, C.; Erzurum, S.; Kalayci, O. Oxidative stress and antioxidant defense. *World Allergy Organ. J.* **2012**, *5*, 9–19. [\[CrossRef\]](#) [\[PubMed\]](#)
37. Abba, M.J.; Banga, A.K. Quantification of skin penetration of antioxidants of varying lipophilicity. *Int. J. Cosmet. Sci.* **2013**, *35*, 19–26. [\[CrossRef\]](#) [\[PubMed\]](#)
38. Blaak, J.; Staib, P. The Relation of pH and Skin Cleansing. *Curr. Probl. Dermatol.* **2018**, *54*, 132–142. [\[CrossRef\]](#) [\[PubMed\]](#)
39. Afsharnezhad, M.; Shahangian, S.; Panahi, E.; Sariri, R. Evaluation of the antioxidant activity of extracts from some fruit peels. *Casp. J. Environ. Sci.* **2017**, *15*, 213–222.
40. Nesseem, D. Formulation of sunscreens with enhancement sun protection factor response based on solid lipid nanoparticles. *Int. J. Cosmet. Sci.* **2011**, *33*, 70–79. [\[CrossRef\]](#) [\[PubMed\]](#)
41. Kim, S.M.; Oh, B.H.; Lee, Y.W.; Choe, Y.B.; Ahn, K.J. The relation between the amount of sunscreen applied and the sun protection factor in Asian skin. *J. Am. Acad. Dermatol.* **2010**, *62*, 218–222. [\[CrossRef\]](#)
42. Berkey, C.; Oguchi, N.; Miyazawa, K.; Dauskardt, R. Role of sunscreen formulation and photostability to protect the biomechanical barrier function of skin. *Biochem. Biophys. Rep.* **2019**, *19*, 100657. [\[CrossRef\]](#) [\[PubMed\]](#)