

Topical Application of Gayo Arabica Cascara Extract: In Vivo SPF and Anti-Photoaging Effects

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ABSTRACT

The increased production of coffee cascara pulp provides a possibility for long-term use in high-value applications such as cosmeceuticals. This study investigated the sun protection factor and anti-photoaging effects of cream made from Gayo Arabica cascara pulp extract in Wistar rats exposed to UV-B rays. GC-MS characterisation of ethanolic extracts revealed 30 bioactive chemicals, with the majority being 5-hydroxymethylfurfural (22.3%), caffeine (21.1%), and n-hexadecanoic acid (12.9%). The extract has total phenolic and flavonoid levels of 101.2 ± 2.5 mg GAE/g and 84.3 ± 1.9 mg QE/g. Cream with 5%, 7.5%, and 10% cascara extract were applied topically for four weeks. Histological investigation with Masson's trichrome staining revealed considerable restoration of collagen density, with the 7.5% group demonstrating the maximum improvement ($64.35 \pm 1.76\%$ vs. $50.13 \pm 0.80\%$ in untreated UVB skin, $p < 0.05$). Sun protection factor was measured using UV visible spectrophotometry, and skin condition was monitored through Dermoscopy. The treated groups showed a notable reduction in redness, pigmentation, and dryness compared to the control group. These results highlight the promise of Gayo Arabica cascara pulp extract as a natural skincare product to protect against UV related skin damage. Additional studies in humans are recommended to confirm these benefits.

Key words: Photoaging; cascara pulp; topical antioxidant; gayo arabica coffee; sun protection factor.

1 INTRODUCTION

Progressive loss of physiological function of the skin led to skin aging. Numerous biochemical and biological changes are involved in this process. Research stated that long-term exposure to UV rays from the sun can accelerate skin aging (Tobin, 2017). Individuals residing in countries in the equatorial area, such as Thailand, Malaysia, and Indonesia, are prone to photoaging due to increased and prolonged exposure to UV rays (Janjai et al., 2010). UV exposure results in DNA damage, immunosuppression, and inflammation in the skin, leading to wrinkles, skin pigmentation, erythema, and telangiectasis (Huang & Chien, 2020).

Oxidative stress is reported to induce photoaging by activating activator protein-1 and promoting the release of proinflammatory cytokines. Consequently, oxidative stress damages the structural proteins of the skin and promotes photoaging (Rinnerthaler et al., 2015). The skin has to be protected against UV rays from the sun to prevent pathological photoaging. The usage of sunscreen and proper clothing to cover the skin can exert protective effects on the skin. The effectiveness of sunscreen is measured based on the sun protection factor (SPF) level (Young, Claveau, & Rossi, 2017). The surface of the skin layer can be examined using dermoscopy (Ankad et al., 2020).

In dermatology, the safety of phytoproducts is considered to be higher than that of conventional therapeutic products (Reuter, Merfort, & Schempp, 2010). Secondary metabolites in plants have potential therapeutic applications,

including dermatological applications. Various medical cosmetics or “cosmeceuticals” have been developed using plant-based products (Lima Cherubim et al., 2020). Natural sources with antioxidant potential, such as coffee cascara pulp, can serve as active components in sunscreen formulations (Mendes dos Santos et al., 2024).

The high quality of Gayo Arabica coffee is closely linked to its favorable agroecological growing conditions (Purba et al., 2020). Coffee processing results in the generation of a large number of wastes, such as cascara pulp, which is currently not optimally utilized as a valuable product. Although rich in antioxidants, the extract is frequently treated as waste and discarded, thereby adding to environmental pollution (Eckhardt et al., 2022). Previous studies have examined the potential of cascara pulp extract from Gayo Arabica coffee to alleviate photoaging-induced damage with promising results obtained for skin collagen production (Lestari et al., 2023). This study sought to clarify the mechanism of the photoprotective action of cascara pulp from Gayo Arabica coffee by assessing the SPF level of a cream containing cascara pulp extract and the dermoscopic features of rats treated with this cream and subjected to UV radiation.

2 MATERIAL AND METHODS

The extract was collected from processing waste of Gayo Arabica coffee (*Coffea arabica* L) collected in Bener Meriah Regency, Aceh, Indonesia. After being milled and shade-dried, the cascara was macerated for 72 hours in 96%

ethanol (technical grade, PT Brataco, Indonesia). To create a thick ethanolic extract, the filtrate was concentrated using a rotary evaporator (Heidolph, Germany) at 40°C under reduced pressure (Lestari et al., 2022). Stearic acid (12%), cetyl alcohol (3%), triethanolamine (1%), glycerin (5%), liquid paraffin (5%), propylparaben (0.02%), methylparaben (0.1%), oleum rosae, and distilled water (q.s. to 100%) were combined to create the base cream, which was utilized for the negative control (PN) group.

Formulations containing 5%, 7.5%, and 10% pulp cascara extract of the active material were prepared based on validated concentrations (Lestari & Hajar, 2023). All cream components were pharmaceutical quality and supplied by the Pharmacy Laboratory at Universitas Syiah Kuala. The positive control employed a cream with 3% L-ascorbic acid ($\geq 99\%$ purity, Sigma-Aldrich, USA), manufactured using the same base cream.

The identification of bioactive components in the cascara pulp extract was performed using gas chromatography mass spectrometry (GC-MS, Shimadzu GCMS-QP2010S, Japan). A volume of 1 mL of the extract, which had been previously mixed with 96% ethanol, was placed into a microtube for examination. The GC-MS system was operated with an injector temperature set at 280°C, using split-less injection, and helium served as the carrier gas. The oven temperature started at 40°C and was increased at a rate of 10°C/min, followed by a hold for 3 minutes. It was then further increased at 30°C/min until it reached 299°C. The total duration of the analysis was 29.633 minutes. The detector temperature remained constant at 280°C. The pressure of the carrier gas was 4.3367 psi, with a total flow of 8.4 mL/min, and a column flow rate of 0.9 mL/min. The split ratio was 5:1. The column used for analysis was an Rti-1MS capillary column with a length of 30.00 meters (Ifmalinda et al., 2018).

The ethanolic extract of Gayo Arabica cascara pulp underwent preliminary phytochemical screening in accordance with conventional methods (Ikhwan et al., 2018). The extract showed positive results for alkaloids (Wagner's test), flavonoids (Shinoda test), saponins (foam test), tannins (Ferric chloride test), and phenolic compounds. The extract had a total phenolic content (TPC) of 101.2 ± 2.5 mg GAE/g extract and a total flavonoid content (TFC) of 84.3 ± 1.9 mg QE/g extract, as determined by the Folin-Ciocalteu and aluminum chloride colorimetric techniques (Kurniasari et al., 2024).

Collagen fiber density in rat skin samples was assessed histologically in accordance with Junqueira et al. (1979), with slight alterations. Following treatment, skin specimens were fixed in 10% neutral-buffered formalin, dried with graded ethanol, cleaned in xylene, and embedded in paraffin. Collagen density (%) was calculated using ImageJ software (NIH, USA) as the area fraction of blue-stained collagen compared to total skin area.

This study received ethical approval from the Veterinary Ethics Committee (Approval No. 130/KEPH/XII/2021). Male Wistar rats (*Rattus norvegicus*), 2 to 3 months old and weighing between 150 and 200 grams, were selected due to the anatomical and physiological similarities of their skin to that of adult humans. The use of male subjects was intended to eliminate hormonal cycle-related variability. The animals were randomly divided into five groups: PN (negative control, administered placebo cream), PP (positive control, treated with 3% L-ascorbic acid), and three treatment groups (P1, P2, P3) receiving topical formulations containing 5%, 7.5%, and 10% of Gayo Arabica cascara pulp extract, respectively. Skin samples were fixed in 10% buffered formalin, embedded in paraffin, sectioned (5 μ m), and stained with Masson's trichrome to identify collagen fibers. Images were taken at 400 $\times$ magnification with an Olympus CX43 microscope, and collagen density (%) was calculated using ImageJ software.

The SPF was evaluated using a UV-Vis spectrophotometer (Shimadzu UV-1800, Japan) with absorbance measurements in the 290–320 nm range. The dorsal region of each rat was shaved to ensure uniform irradiation before UV-B exposure. The animals were subjected to UV-B radiation using a Kernel KN-4003 lamp three times per week for four consecutive weeks, reaching a total cumulative dose of 840 mJ/cm². Following the final exposure, all animals were humanely euthanized via cervical dislocation. Dermoscopic examinations were subsequently performed to assess photoaging-related skin alterations, including diffuse erythema, hypo- or hyperpigmented macules, reticular pigmentation, and xerosis.

Data were analyzed using SPSS software (IBM Corp., Armonk, NY, USA). Normality of data distribution was determined using the Shapiro-Wilk test. Means were compared using a one-way analysis of variance if the data exhibited homogeneous variance or normal distribution.

3 RESULTS

Based on the GC MS analysis of the Gayo Arabica coffee cascara pulp extract as shown in Figure 1, a total of 30 chemical compounds were identified using 96% ethanol as the extraction solvent. The major constituent was 5-hydroxymethylfurfural with relative abundance of 22.31%, followed by caffeine at 21.07% and n-hexadecanoic acid at 12.85%. The earliest detected compound was formic acid at a retention time of 3.145 minutes with a concentration of 0.54%, while the final peak appeared at 37.002 minutes corresponding to 9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester (1-monoolein) (0.95%). The major compound identified was 5-hydroxymethylfurfural, which was eluted at 21.337 minutes.

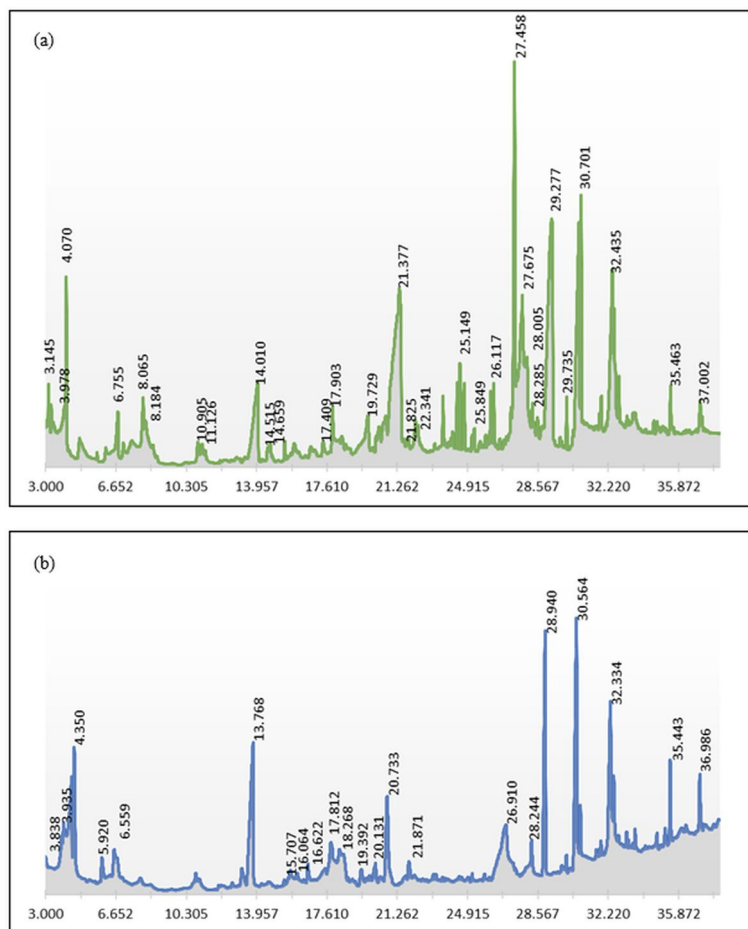


Figure 1: (a) GC-MS chromatogram of *Gayo Arabica coffee cascara pulp* extracted with 96% ethanol, indicating high peak intensity and a wide variety of antioxidant compounds. (b) GC-MS chromatogram of *Gayo Arabica coffee cascara pulp* extracted with distilled water, showing fewer peaks and lower intensity, suggesting less efficient recovery of bioactive components.

A comparison of GC-MS results between the ethanol and water extracts of Gayo Arabica coffee cascara demonstrated notable differences in their phytochemical content. The extract obtained with ethanol exhibited a greater number of peaks with higher intensity across various retention times, reflecting a richer presence of bioactive compounds such as 5-hydroxymethylfurfural, caffeine, and 2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one. These compounds have been widely reported for their antioxidant, anti-inflammatory, and photoprotective activities (Li et al., 2021). On the other hand, the water-based extract presented a simpler chromatographic profile with fewer active components, indicating that water was less effective in extracting certain non-polar or semi-polar phytochemicals.

These results are in agreement with earlier research that recognized ethanol as a more efficient solvent for extracting phenolic compounds, flavonoids, and other antioxidants from plant-based materials (Kurniasari et al, 2024). As a non-polar solvent, ethanol is capable of dissolving a broader spectrum of secondary metabolites, especially those linked to UV-

protective properties (Catelan et al., 2019). Therefore, the richer phytochemical content observed in the ethanol extract supports its application in developing antioxidant enriched topical creams aimed at photoaging prevention. This indicates that ethanol is a more appropriate extraction solvent for topical formulations derived from Gayo Arabica cascara, intended to enhance skin protection and delay signs of photoaging, while also contributing to the sustainable use of coffee processing byproducts.

Several additional antioxidant compounds were identified in the extract. These included phenol, 3,5-bis(1,1-dimethylethyl), an alkylbenzene known for its antibacterial, antifungal, anti-inflammatory, and anticancer effects. Another compound detected was 5-hydroxymethylfurfural, a furfural derivative commonly formed during heating or storage of food, which possesses notable antioxidant activity (Navajas-Porras et al., 2022). The extract also contained 5-acetoxymethyl-2-furaldehyde, a related furfural compound involved in modulating sweetness perception (Hedda Hillmann et al., 2012). Caffeine, a xanthine alkaloid with antioxidant, central

nervous system stimulant, and plant defense functions, was also present (Nadanasabapathi, 2013). Corymbolone, an eudesmane-type sesquiterpenoid reported to interact with 7TLK target receptors (Mandik et al., 2022) was detected as well. In addition, n-hexadecanoic acid was found, a compound associated with antioxidant, anti-inflammatory, pesticidal, antimutagenic, cytoprotective, hypocholesterolemic, and fibrinolytic properties (Mazumder et al., 2020). Among these, three compounds with the highest concentrations—5-hydroxymethylfurfural, 2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one, and caffeine—are discussed further due to their significant contribution to the antioxidant potential of the Gayo Arabica cascara pulp extract cream.

Phytochemical analysis found that the Gayo Arabica cascara pulp extract contains alkaloids, flavonoids, tannins, saponins, and polyphenols. Alkaloids may have antibacterial and anti-inflammatory properties, whereas flavonoids and polyphenols are powerful antioxidants and UV protectors. Tannins promote collagen stability, while saponins may increase skin penetration and minimize inflammation. These bioactive ingredients contribute to the extract's potential as a topical anti-photoaging agent Table 1.

Table 1: The results of the qualitative test of the phytochemical content of cascara pulp extract.

Test	Result	Description
Alkaloids		
<i>Dragendrof</i>	+	Orange-brown sediment formed
<i>Mayer</i>	-	White color is not formed
<i>Wagner</i>	+	A reddish color has formed
Flavonoids	+	A red solution is formed
Tannins	+	A cloudy white solution is formed
Saponins	+	A bubble formed
polyphenol	+	A bluish-black color is formed

Collagen fiber density differed considerably among groups (Kruskal-Wallis, $p < 0.05$), show in Tabel 4 and 5. P3 had the highest collagen density ($64.35 \pm 1.76\%$) after applying a cream with 7.5% Gayo Arabica cascara pulp extract, while PN had the lowest ($50.13 \pm 0.80\%$) after using a placebo cream. Chronic UVB exposure triggers the creation of reactive oxygen species (ROS), activating signaling pathways such as MAPK, AP-1, and NF- κ B. This leads to inflammation and the release of matrix metalloproteinases (MMPs) (Potekaeve et al., 2021). These enzymes destroy extracellular matrix components, such as collagen, causing fragmentation, thinning, and diminished tensile strength. The current findings are consistent with prior research that found UV radiation reduces collagen content and fiber density in cutaneous tissue (Budden et al., 2021), Table 2.

Table 2: Collagen density (%) in UVB-exposed rat skin treated with pulp cascara cream.

Group	Mean $\pm$ SD (%)	Kruskal-Wallis test	
		Score	P Value
PP	61.09 ± 0.49^{bc}	23.170	0.000
PN	50.13 ± 0.80^a		
P1	53.65 ± 1.26^a		
P2	58.05 ± 1.51^b		
P3	64.35 ± 1.76^c		

Description:

PN = negative control

PP = positive control

P1 = 2.5% pulp coffee extract

P2 = 5% pulp coffee extract

P3 = 7.5% pulp coffee extract

Histological analysis of Masson's trichrome-stained collagen fibers revealed significant intergroup variations, show in Figure 2 and table 3. The positive control (PP) showed dense, well-organized, and evenly distributed bundles, indicating intact dermal architecture (Junquiera et al., 2013). The negative control (PN) exhibited lower density and disordered fibers, indicating extracellular matrix breakdown owing to photoaging (Yehia et al., 2021). Treatment groups showed progressive improvement, with P3 exhibiting collagen morphology similar to PP, indicating significant repair and protection against UVB-induced damage (Hamid et al., 2024).

Dermoscopic analysis of the dorsal skin revealed minimal wrinkles, minimal erythema, no pigmentation or yellowish color, and no telangiectasis in the P1, P2, and P3 groups. In contrast, rats in the PN group exhibited widespread erythema and rough wrinkles. The dermoscopic features are shown in Table 1.

The results of the statistical analysis indicate that there are no significant differences in the dermoscopic variable among the groups PP, P1, and P2. The group P3 exhibits significant differences compared to the negative control group (PN).

The SPF test results (Table 3) revealed that Gayo Arabica coffee exerts protective effects against UV rays. The SPF levels of the extract were high at concentrations of 10%, 20%, and 30%, moderate at concentrations of 5% and 7.5%, and between high and moderate at a concentration of 10%, show in Tabel 6.

4 DISCUSSION

The current study shows that Gayo Arabica cascara pulp extract has anti-photoaging properties, as indicated by improved SPF values, collagen density, and dermoscopic skin appearance in UVB-exposed Wistar rats. The most common chemicals, according to GC-MS profiling, were

5-hydroxymethylfurfural, caffeine, and n-hexadecanoic acid. Caffeine has been shown to have photoprotective benefits by improving DNA repair and lowering UV-induced oxidative stress, whereas polyphenols and flavonoids can inhibit matrix metalloproteinases (MMPs), protecting collagen integrity (Nichols et al., 2011).

Coffee and its byproducts are reported to impart health benefits, including skin health benefits (Mello de et

al., 2023). The consumption of coffee mitigates photoaging (Fukushima et al., 2020). However, the bioavailability of the bioactive compounds of coffee is poor when consumed via the oral route. Hence, direct drug delivery to the skin via topical application has several advantages, such as preventing first-pass metabolism, ease of usage, non-off-target effects, and easy termination in case of adverse events (Anchal et al., 2021).

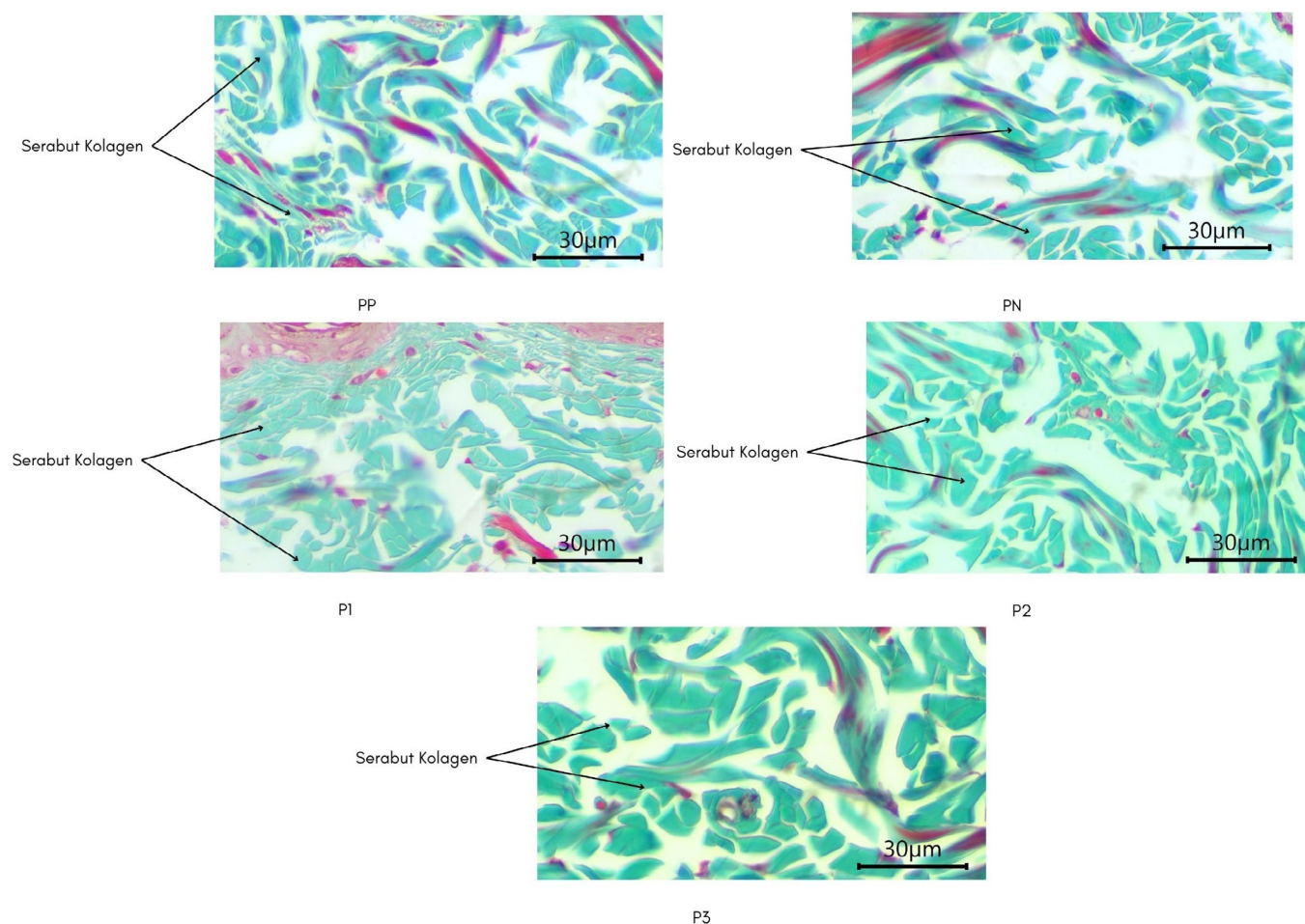


Figure 2: Histological photographs of skin preparations (PP, PN, P1, P2, and P3) were stained with Masson's Trichrome to reveal collagen fibers (at 400× magnification). Scale bar: 30 μm.

Table 3: Alterations in Dermoscopy Noted Following UV-B Exposure and Intervention.

Dermoscopic Features	PN		PP		P1		P2		P3	
	n	%	n	%	n	%	n	%	n	%
Difuse erytema	5	100	3	60	2	40	1	20	0	0
Hypo/Hyperpigmented macule	5	100	2	40	2	40	2	40	1	20
Reticular pigmentation	5	100	2	40	2	40	2	40	1	20
Xerosis	3	60	3	60	3	60	2	40	1	20

Kruskal-Wallis test p-value was less than 0.05, indicating that the null hypothesis (H0) was rejected, and the alternative hypothesis (H1) was accepted. Thus, the dermoscopic characteristics varied between the treatment groups. The dermoscopic data of the experimental groups are displayed in Table 2.

Table 4: The Kruskal-Wallis test results for dermoscopic features.

Test Statistics	Values
Kruskal-Wallis H	15.770
df	4
Asymp. Sig. (p)	0.003

P < 0.05 indicates that there is a significant difference between the treatment groups.

Table 5: Mean Rank of Groups in the Kruskal-Wallis Test.

	Group	N	Mean Rank
Dermoscopic Features	PN	4	18.13 ^a
	PP	4	12.50 ^{ab}
	P1	4	11.00 ^b
	P2	4	8.00 ^{bc}
	P3	4	2.88 ^c
	Total	20	

Values that do not share the same superscript letter indicate a significant difference at $p < 0.05$ (Duncan's Alpha Test).

Table 6: Evaluation of Sun Protection Factor of pulp cascara pulp extract cream at different concentrations.

Concentration	SPF Value	Category
5%	3.981	Minimal Protection
7.5%	5.417	Moderate Protection
10%	16.16	Ultraprotection

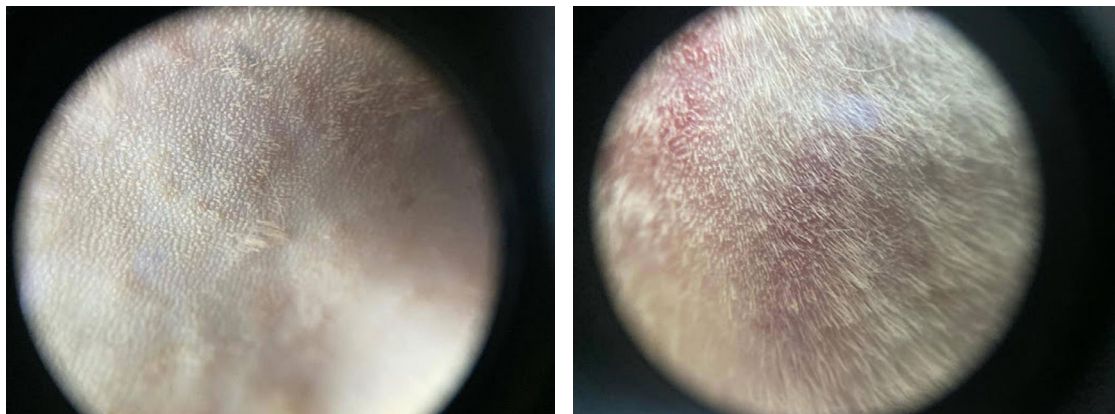
In this study, cascara pulp Gayo Arabica coffee extract cream exerted protective effects against UV rays at all tested concentrations. Additionally, cascara pulp Gayo Arabica coffee extract cream exhibited high SPF levels and protected the skin against UV exposure-induced skin aging in a concentration-dependent manner.

The findings of this study are consistent with those of Nugrahaeni et al. (2021), who reported that the SPF strength of Gayo arabica coffee leaves was the highest (5.54) at the maximum tested concentration of leaf extract (2.5%), indicating a medium level of protection (Nugrahaeni et al., 2021). One study demonstrated that the topical application of cocoa extract prevented UV A ray-induced photoaging by upregulating the antioxidant superoxide dismutase (Indira et al., 2023). Another study reported that *Coffea arabica* coffee, *Coffea canephora*, and *Coffea liberica* can be potential ingredients of sunscreen and that the highest SPF level was exhibited by Gayo Arabica coffee (Latief & Tarigan, 2022).

In addition to regulating photoaging-related biomarkers, the Gayo Arabica coffee extract cream derived from cascara pulp shown protective properties on rat skin. Figure 1 illustrates the advantageous effects of the extract cream on the skin. A dermoscopic assessment of the dorsal integument of rats administered cascara pulp Gayo Arabica coffee extract cream shown a reduction in the appearance of wrinkles, minimal erythema, no pigmentation or yellowish color, and no telangiectasis. Meanwhile, rats in the negative control exhibited widespread erythema and coarse wrinkles. A previous study examined the impact of purple variation passion fruit seed extract cream (3%) (*Passiflora edulis* Sims var. *Edulis*) on facial skin aging. The clinical dermoscopic examination revealed decreased dermoscopic photoaging scale scores and mitigated yellowish discoloration, telangiectasis, wrinkles, and erythema after 8 weeks of application show in Figure 3. (Muslim, Jusuf & Putra., 2023).

5 CONCLUSIONS

Gayo Arabica cascara pulp extract showed substantial anti-photoaging properties in a UVB-induced rat model, as seen by increased SPF, dermoscopic improvement, and histological evidence of collagen preservation. The 7.5% formulation produced the highest collagen density, while the 10%

**Figure 3:** Dermoscopic examination of (A) rats in the negative control group and (B) rats treated with cascara pulp Gayo Arabica coffee extract cream.

formulation offered the best SPF protection. These findings highlight cascara pulp extract's potential as a sustainable, antioxidant-rich component for cosmeceutical applications, providing health benefits while also maximizing the use of coffee industry waste. Additional human investigations are needed to confirm these findings and enhance formulations for therapeutic usage.

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7 AUTHOR CONTRIBUTIONS

Conceptual Idea: Nur, N.; Tawali, A. B; Laga, A.; Reta. Methodology design: Nur, N.; Tawali, A. B; Laga, A.; Reta. Data collection: Nur, N., Data analysis and interpretation: Nur, N.; Tawali, A. B; Laga, A.; Reta., Writing and editing: Nur, N. ; Tawali, A. B; Laga, A.; Reta.

8 DATA AVAILABILITY STATEMENT

Data available upon request to authors.

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