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Cosmeceutical Potential of *Artocarpus camansi* Fruit Peel Extract as Bioactive Ingredient in Topical Serum Formulation

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ABSTRACT

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The global use of plant-based cosmetics has increased dramatically as consumers become more aware of the long-term health advantages of natural products. The Philippines, a tropical Asian country, has numerous local plant resources with promising medicinal value while preserving its unique biodiversity and inherited medicinal value. The present study deals with the utilization of *Artocarpus camansi* fruit peel extract as bioactive component with pharmacological activity in cosmetic formulation. This experimental research involved extraction of phenolic compounds, formulation of topical serum, and *in vitro* investigation of antibacterial, anti-inflammatory, and photoprotective activity of *A. camansi* topical serum (ACTS). The pure

total phenolic content. Among the three formulations, 5% ACTS was found to be the most effective antibacterial, anti-inflammatory, and photoprotective topical serum compared to 1% and 3%. The results of one-way ANOVA revealed that there was a statistically significant difference among the formulations compared to the positive and negative controls. Post-hoc confirmed that the positive controls provided the highest activity among the treatments. A. camansi fruit peel extract can therefore be identified as a potential bioactive ingredient in cosmetic formulations for serums which can be effective in improving skin and providing protection from the external environment.

INTRODUCTION

The increasing prevalence of skin-related issues has become a significant interest in natural remedies and cosmetic purposes, mainly plant extracts, known for their therapeutic properties. The global use of plant-based cosmetics has increased dramatically as consumers become more aware of the long-term health advantages of natural components. As worldwide demand for herbal cosmetics rises, the Philippines, a tropical Asian country, has numerous chances to enhance its formulation by utilizing local plant resources while preserving its unique biodiversity and inherited traditional expertise. Artocarpus camansi is a perennial tree species, which in its original habitat is often collected from the wild for food and materials purposes. (Ragone, 2006). Tsai et al. (2013) isolated and identified four phytochemical compounds from the leaves and three from the stem of *A. camansi*. Nasution et al. (2020) extracted lupeol, a triterpene from *A. camansi* fruit peel, and Hashim et al. (2011) tested a different triterpenoid from *Centella asiatica* as a photoprotective agent against ultraviolet light. Consequently, several documents revealed that different classes of secondary metabolites possess a range of pharmacological activities like antibacterial and anti-inflammatory effects. This study would address a limited understanding of the specific mechanisms by which *A. camansi* exerts its antibacterial, anti-inflammatory, and photoprotective effects. Likewise, it will introduce a new method for creating the best possible formula to improve the stability and effectiveness of the serum from *A. camansi* by trying out different carriers or ways to extract it. In the same way, this study will give information on how sustainable it is to get *A. camansi* and its effects on the environment. This study examined how the extract from the peel of *A. camansi*fruit could be used in a skin serum. It focused on its ability to fight bacteria, block the harmful UV radiation, and reduce inflammation by combining recent research and finding areas where more study is needed. The study aims to create a new skincare product by examining the beneficial substances in the extract. This

product will help common skin problems and improve overall skin health and resilience against environmental influences.

OBJECTIVES OF THE STUDY

This study aimed to extract and quantify the phenolic compounds as the bioactive ingredient in *Artocarpus camansi*fruit peel, and formulated into topical serum. Consequently, this study utilized the serum to determine 1) the antibacterial activity using agar will diffusion method, 2) the anti-inflammatory activity using protein denaturation inhibition assay, and 3) the photoprotective activity using ultraviolet spectral absorbance technique.

METHODS AND PROCEDURES

Research Design

This study utilized the true experimental and completely randomized research design. The experimental groups contain the varying concentration of *Artocarpus camansi* fruit peel extract while the control groups include the negative control (serum base) and the positive control for antibacterial (mupirocin), anti-inflammatory (betamethasone), and photoprotective (commercial sunblock). Randomization was assigned to *Staphylococcus aureus* culture, albumin standard, and UV-exposed treatments.

Plant Extraction

The peels of *Artocarpus camansi* fruit were locally sourced in Kalibo. The peels were washed three times with tap water and subsequently rinsed with distilled water to eliminate any contaminants on the surface. The fruit peels were positioned in an automated electric dehydrator at a temperature of 50°C. The desiccated fruit peels were ground utilizing an electric dry granulator. Two hundred fifty grams of powdered fruit peels were transferred in an Erlenmeyer flask and treated with enough ethyl acetate to fully immerse the plant sample for 48 hours. The filtrate (ethyl acetate extractive) was separated, and the plant residue was discarded. The filtrate was concentrated under a vacuum with a rotating evaporator at a temperature not above 50°C. The extract was subsequently stored in a glass bottle and refrigerated until biological experiment was conducted (Claustra et al., 2005).

Determination of Total Phenolic Compound

The total amount of phenolic compounds in *A. camansi* was measured using

the Folin-Ciocalteu method (Odabasoglu et al., 2004). A standard curve for gallic acid was created by making solutions with different concentrations (0.1, 0.5, 1.0, 2.5, and 5 mg/ml) in methanol, starting from a standard solution of gallic acid. 100 µl of each of these solutions were mixed with 500 µl of water, followed by 100 µl of Folin-Ciocalteu reagent, and left for 6 minutes. One (1) ml of 7% sodium carbonate and 500 µl of distilled water were added to the mixture. The absorbance was measured after 90 minutes using a spectrometer at 760 nm. The same process was done with the pure extract. Gallic acid equivalents (mgGAE/g) was calculated using the standard calibration curve in figure 1. To ensure accuracy, all experiments were conducted three times.

Topical Serum Formulation

The formulation of *A. camansi* topical serum was based on the method of Zahara et al. (2023) with modifications in the composition. Table 1 shows the treatments and the composition of active ingredients and the excipients.

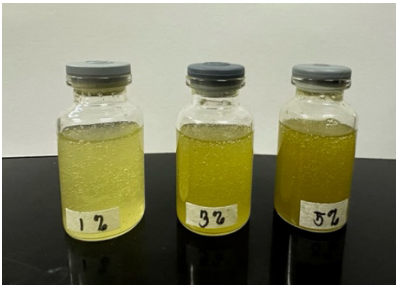
Table 1

Composition of Topical Serum

Composition	Treatment A (1% *A. camansi*)	Treatment B (3% *A. camansi*)	Treatment C (5% *A. camansi*)	Treatment D (Serum Base)	Treatment E (Positive Control)
A. camansi extract	1.00 %	3.00 %	5.00 %	0.00 %	Commercial Topical Preparations with Antibacterial, Anti-inflammatory, and Photoprotective Claims
Carbopol	99.00 %	97.00 %	95.00 %	100.00 %	
Xanthan gum					
Glycerin					
Propylene glycol					
Triethanolamine					
Phenoxyethanol					
Citrus essence					
Distilled water (q.s.)					

The process of preparing the topical serum gel commenced with the formulation of mixture A, which involved the careful dispersion of 0.5 g of Carbopol and 1.0 g of xanthan gum into 30.0 ml of hot water at a temperature of 50°C, followed by allowing it to swell appropriately. Subsequently, 0.2 g of triethanolamine was incorporated into mixture A, and the combination was stirred with a homogenizer until a viscous consistency was achieved. The mixture A is subsequently placed aside for further consideration. The preparation of

mixture B involved the careful addition of 0.5 g of phenoxyethanol and 2.0 g of glycerin to 10.0 ml of hot water maintained at 50°C. The components were mixed well to create a uniform solution and then set aside for later use. For mixture C, A. camansi fruit peel extract was carefully added to 3.0 mL of glycerin, making sure it was thoroughly blended. After that, 5.0 mL of propylene glycol was added and mixed until a consistent texture was reached. Mixture C was subsequently incorporated into mixture B gradually, while stirring with a homogenizer at a consistent speed until a uniform consistency was achieved. The combined mixture B-C was gradually incorporated into mixture A, ensuring a thorough blend was achieved. The prepared serum was subsequently allowed to rest for a period of 24 hours to facilitate the elimination of any bubbles that may have developed during the mixing process.



Finished Product (*Artocarpus camansi* Topical Serum)

Antibacterial Testing

Thirty-eight grams of Mueller-Hinton agar (MHA) were accurately measured using an analytical balance with an aluminum weighing pan. The MHA was subsequently transferred to an Erlenmeyer flask and rehydrated using 1000 ml of distilled water. The MHA solution underwent heating on an electric hot plate to achieve thorough dissolution. The MHA solution was permitted to solidify for a duration of four hours. The MHA was then sterilized in an autoclave at 121°C under 15 psi for 15 minutes. About 25ml of MHA was carefully dispensed into dry and sterile petri dishes within the confines of the Biosafety Cabinet II A2. The agar was permitted to solidify for a duration of fifteen minutes. Subsequently, the agar plates were inverted to prevent any moisture that accumulated inside the cover from dripping onto the surface of the culture medium.

A sterile L-shaped applicator was dipped into the suspension of the test organism and was then carefully swabbed onto a solidified Mueller-Hinton agar plate by rotating the applicator over the entire surface of the agar plate in a full 360-degree motion, ensuring an even distribution of the inoculum across

the surface medium. A 6-mm Whatman filter paper disc was sterilized using an autoclave. Then a volume (20–100 µL) of the treatments (1%, 3%, 5% *A. camansi* Topical Serum) was introduced into the disc until totally saturated. The disc was then placed on the surface of the agar plate which had previously been inoculated with the microorganism. The plates were incubated under 37 degrees Celsius at 18-24 hours. The measured zones of inhibition were determined using a digital vernier caliper and have the following inferences: inactive (<10mm), partially active (10 to 13 mm), active (14 to 19 mm), and very active (>19 mm). All tests were conducted in triplicate. One-way ANOVA followed by post-hoc Scheffe's test were used to assess the statistical significance, and a p-value of less than 0.01 was deemed significant.

Anti-inflammatory Testing

A serial dilution in multiple of 10 from 0.01 µg/ml to 1000 µg/ml was performed for each treatment and for the reference drug (betamethasone). All samples contained 5.0 ml of total volume. Reaction mixtures were prepared using 2.8 ml of phosphate-buffered saline (pH 6.4) and 0.2 ml of egg albumin (from a fresh hen's egg). Then 2 g of samples from each different concentration were mixed gently with reaction mixtures. A similar procedure was used for reference drugs (betamethasone), and they were used as positive controls for this study. In addition, normal saline solution was used as a negative control.

The reaction mixtures (phosphate-buffered saline solution, albumin, and treatments) were incubated at 37°C ± 2°C for 15 to 20 minutes, and then subsequently heated to 70°C, where they were held for 5 minutes. The reaction mixture was cooled down at room temperature for 15 min. The absorbance of the reaction mixture before and after denaturation was measured for each concentration (1000 µg/ml, 100 µg/ml, 10 µg/ml, 1 µg/ml, 0.1 µg/ml and 0.01 µg/ml) at 680 nm using a colorimeter. Each test was repeated thrice, and the mean absorbance was recorded. The percentage of inhibition of protein was determined on a percentage basis with respect to control using the following formula.

$$\text{Percentage inhibition (\%)} = \frac{\text{Absorbance (control)} - \text{Absorbance (test)}}{\text{Absorbance (control)}} \times 100$$

Photoprotective Testing

Ten (10) mg of each sample was dissolved in 100 ml of methanol to achieve

a 100 µg/ml concentration. The solution was then homogenized for 10 minutes and filtered using Whatman filter paper. *A. camansi* topical serum was analyzed across 200 nm to 400 nm wavelength (Abbas et al., 2017) using a UV-visible spectrophotometer, with measurements taken in triplicate. The absorption spectra were recorded using a 1 cm quartz cell, utilizing the spectra measurement mode and a reference cell filled with methanol as the pure solvent (Kaur & Saraf, 2011). The absorption spectra and characteristic peaks of all treatments were recorded. There is a significant need to investigate the sunburn protective properties of plants that have established medicinal benefits and are rich in phytoconstituents. The effectiveness of a sunscreen agent is typically indicated by the SPF, which is calculated as the UV energy needed to cause a minimal erythema dose (MED) on skin that is shielded, divided by the UV energy needed to create a MED on skin that is exposed (Kaur & Saraf, 2010; Mishra et al., 2012).

$$SPF = \frac{\text{Minimal Erythemal Dose of Protected Skin}}{\text{Minimal Erythemal Dose of Unprotected Skin}}$$

Topical sunscreen formulations or extracts underwent UV radiation exposure to evaluate their protective efficacy in vivo or in vitro. Human volunteers are employed for in vivo evaluation; nonetheless, this method is laborious and harmful to the skin (Wulf, 2009; Wood & Murphy, 2000). The optimal method for determining SPF is through in vitro analysis, which involves measuring the absorption or transmission of UV radiation. The serums were subjected to further processing to determine the SPF (Mohamad et al., 2018). A 100 µg/ml stock solution was employed to determine the SPF of different formulations, which were evaluated at wavelengths from 290 to 320 nm in 5 nm increments. Measurements were taken three times for each concentration using a 1 cm quartz cell, with methanol serving as the blank. Mansur et al. (1986) developed a simple mathematical equation that substitutes the in vitro method proposed by Sayre et al. (1979) using a UV spectrophotometer. The formula below was used to calculate the SPF, and the Equation is,

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

Where CF = Correction Factor (10), EE (λ) = Erythrogenic Effect of radiation, I (λ) = Solar Intensity spectrum, Abs (λ) = Spectrophotometric absorbance value. The values of EE x I are constants, and are shown in table 2:

Table 2

Normalized product function used in calculation of SPF

Spectrum No.	Wavelength (*X*)	EE X I (normalized)
1	290	0.0150
2	295	0.0817
3	300	0.2874
4	305	0.3278
5	310	0.1864
6	315	0.0839
7	320	0.0180
		Total = 1.0000

Research Ethics Protocol

This study followed ethical standards for research involving laboratory procedures and microorganisms. The use of Artocarpus camansi fruit peel was in line with sustainability principles, making use of agricultural by-products to reduce waste. Laboratory practices adhered closely to biosafety guidelines to guarantee the safe handling and disposal of bacterial cultures and other potentially hazardous materials. Since no human or animal subjects were involved, concerns about direct harm or consent from living organisms were eliminated. Likewise, waste disposal and disinfection were strictly followed to avoid the spread of infection. Consequently, the study emphasizes transparency, reproducibility, and responsible result communication as critical factors for upholding scientific integrity and public trust.

RESULTS AND DISCUSSION

Ethyl acetate, a relatively polar organic solvent, was used in this study to extract polyphenols. Research studies have been conducted on *A. camansi* using ethyl acetate as a solvent (Nasution et al., 2020; Vianney et al., 2018). Thus, it became a reliable means to assess the antibacterial, anti-inflammatory, and photoprotective activities. Moreover, ethyl acetate is relatively nontoxic, biodegradable, and supports sustainable extractions consistent with the green chemistry principle (Piotrowski & Kubica, 2021).

Polyphenols are secondary metabolites found in a variety of plants, including many fruits, vegetables, and herbs. Recently, they have attracted significant public interest. About 10,000 different bioactive compounds with a wide range of structural variations (Li et al., 2014). Gallic acid equivalent is a widely accepted standard for quantifying phenolic compounds (Vianney et al., 2018) representing polyphenols.

The table shows the average absorbance for different concentrations of gallic acid; table 3 and figure 1 show the standard gallic acid curve and the regression equation used to calculate the total phenolic content of the extracts. The curve has a value of R2 (0.9694), which is closer to 1.0. Thus, the curve is fit for the determination of phenolic content of *A. camansi* peel extract.

The total phenol content obtained in this study is 22.5mg GAE/g, as shown in Table 4. Based on the literature and present results, *A. camansi* is an important source of phenolic compounds for biomedical applications.

Table 3

Concentration and absorbance of standard gallic acid

Concentration (mg/mL)	Absorbance (Mean) 760 nm
0.1	0.091
0.5	0.224
1.0	0.458
2.5	0.893
5.0	1.329

Figure 1

Calibration curve and regression equation of standard gallic acid

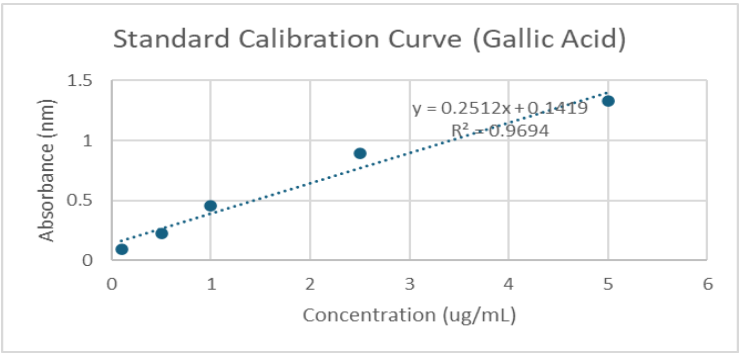


Table 4
Gallic acid equivalent as phenol content of A. camansi peel extract

Trial	Absorbance	Concentration (mg/mL)	% Phenolics
1	0.129	0.006079472	1.21589431
2	0.131	0.013798282	2.759656462
3	0.131	0.013798282	2.759656462
		Average	2.245069078
		GAEmg/g	22.5mg/g

Antibacterial Activity

The agar well-diffusion method was employed to assess the antibacterial effectiveness of ACTS against Staphylococcus aureus, a prevalent pathogen linked to skin infections (Del Giudice, 2020). With the increasing prevalence of antibiotic-resistant bacteria, research into the potential of natural ingredients as antimicrobials continues (Silalahi, 2022). The antimicrobial susceptibility of *S. aureus* isolated from individuals with atopic dermatitis is 85% or lower for β-lactams, erythromycin, fusidic acid, and clindamycin (Elizalde-Jiménez et al., 2024). In addition, the skin microbiota of patients with atopic dermatitis is marked by heightened colonization of *S. aureus*. (Edslev et al., 2021).

Figure 2 revealed that 5% ACTS exhibited a strong antibacterial activity when compared to 1%, 3%, and the negative control. Table 5 shows a significant difference in the zone of inhibition of *S. aureus* at the $p<.01$ level for the five treatments, $F(4, 25) = 268.3515$, $p = 1.1102e-16$). Post-hoc Scheffe test ($p<0.01$) further confirmed that 1%, 3%, and 5% ACTS differ significantly from the positive and negative controls.

The results align with the research conducted by Vianney et al. (2018) regarding the antibacterial properties of A. camansi against different organisms, such as S. aureus and P. aeruginosa. Additionally, the study by Ante et al. (2016) explored the effectiveness of various parts of A. camansi against multidrug-resistant bacteria. Polyphenols are recognized in the Artocarpus genus of plant sources (Hashim et al., 2010; Jayasinghe et al., 2008; Makmur et al., 2000; Sidahmed et al., 2013). Phenolic acids act by preventing bacterial attachment, auto-aggregation, and motility to lessen the pathogenicity of bacteria (Salaheen et al., 2014). The correlation analysis revealed that the antibacterial activity was significantly correlated with the phenolic content (Vianney et al., 2018).

Figure 2
Graph of the zone of inhibition on S. aureus

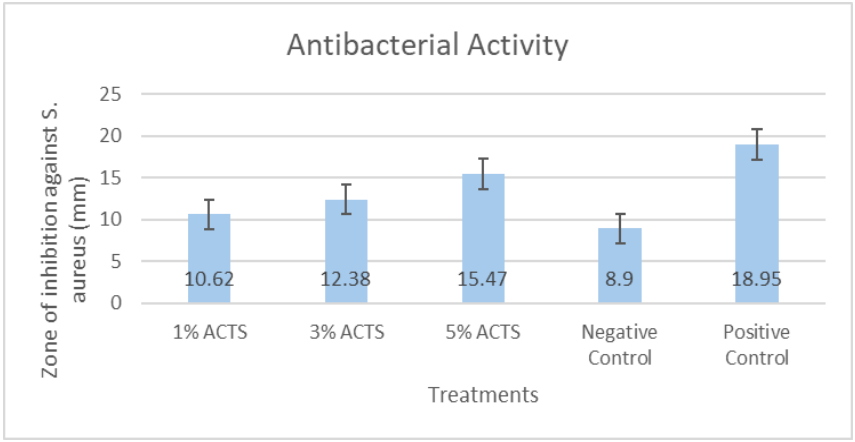


Table 5
One-way analysis of variance on antibacterial activity

source	sum of squares SS	degrees of freedom νν	mean square MS	F statistic	p-value
treatment	384.0647	4	96.0162	268.3515	1.1102e-16
error	8.9450	25	0.3578		
total	393.0097	29			

Anti-inflammatory Activity

Artocarpus plants possess anti-inflammatory activity (Buddhisuharto et al., 2021). Significant activity against edema was previously studied for *A. camansi* leaf extract at both 24- and 48-hours post-challenge on 2,4,6-trinitrochlorobenzene (Salonga et al., 2014). The presence of polyphenols such as steroids and triterpenoids were proven to be present in the fruit peel of *A. camansi* (Nasution et al., 2018). These compounds have anti-inflammatory activity and are promising candidates for the development of anti-inflammatory drugs (Loza-Mejía & Salazar, 2015; Yahfoufi et al., 2018). They act with therapeutic targets associated with inflammation, including COX-1 and -2, LOX-5, MPO, PLA2, and i-NOS12 (Loza-Mejía & Salazar, 2015). Afaq and Katiyar (2011) state that polyphenols can also be used therapeutically in skin inflammation disorders because they inhibit the activation of pro-inflammatory transcription factors like

activator protein 1 (AP-1), NF-κB, or MAPK/Erk. This reduces the release of pro-inflammatory cytokines, tissue-remodeling enzymes, and adhesion molecules.

Figure 3 presented a concentration-dependent inhibitory activity (IC50increases with the increase in % formulation) of ACTS against protein denaturation. Among the different formulations, 5% ACTS exhibited the highest IC50. There was a significant difference among the formulations, $F(4, 10) = 2,835.9732$, $p = 3.2196e\text{-}15$) compared to the reference drug (betamethasone) and the negative control, as shown in Table 6. Post hoc Scheffe test confirmed the significant difference ($p<0.01$). To the author's knowledge, this is the first report on the antiinflammatory activity of *A. camansi* fruit peel as a bioactive ingredient of ACTS.

Figure 3

Graph of the median inhibitory concentration on protein denaturation

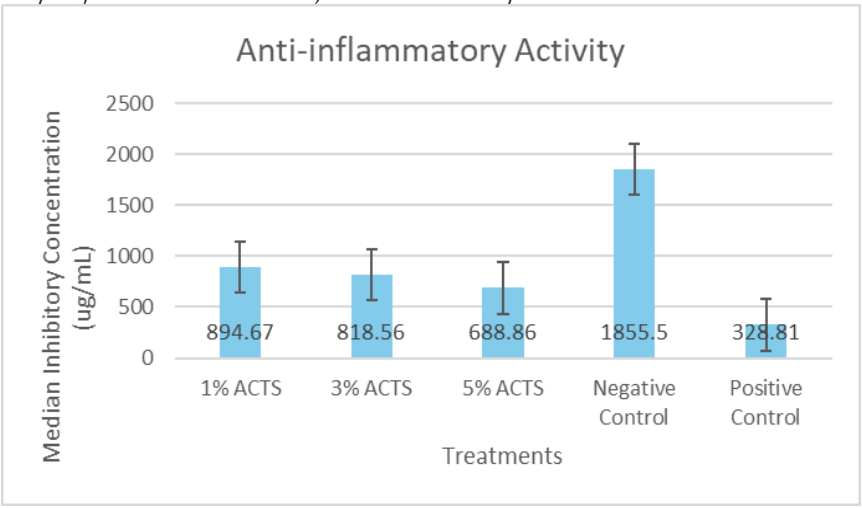


Table 6

One-way analysis of variance on anti-inflammatory activity

source	sum of squares SS	degrees of freedom νν	mean square MS	F statistic	p-value
treatment	3,866,960.8843	4	966,740.2211	2,835.9732	3.2196e-15
error	3,408.8482	10		340.8848	
total	3,870,369.7325	14			

Photoprotective Activity

One of the environmental insults and the most damaging electromagnetic radiation to human skin is ultraviolet (UV) radiation (Dunaway, 2018). In particular, UV-A (315–400 nm) and UV-B (280–315 nm) are the biologically significant components of UV radiation. 80% of the total UV rays represent the UV-A that deeply penetrates the epidermis and dermis layers of the skin, causing numerous severe skin alterations (Bernerd et al., 2022). Consequently, UV-B radiation significantly affects the epidermis (Battie et al., 2014). Chronic exposure to UV-A and UV-B can cause UV-induced reactive oxygen species (ROS), a photooxidative damage including photo aging and photo carcinogenesis on the skin (Martínez et al., 2012).

According to Saraf et al. (2010) and Mbanga et al. (2014), a higher Sun Protection Factor (SPF) indicates an increase in photoprotective activity. Sunscreens are applied to the skin to support the body's defenses against the sun's damaging UV rays.

Plant polyphenols are an essential component of several photoprotective drugs that can lower oxidative stress (Dunaway et al., 2018). These natural compounds have been shown to increase the survival of skin cells exposed to UV irradiation and reduce ROS levels and UV-induced DNA damage (Afaq & Katiyar, 2011; Hu et al., 2017). They are frequently used as constituents in skin anti-aging cosmetics and are applied topically as plant extracts.

Research studies on employing natural compounds as sun protective agents have increased. The photoprotective properties of *A. camansi* have not been previously investigated. This constitutes the initial report of the photoprotective activity of ACTS.

Table 7

Determination of in vitro SPF

Wave length (λ) nm	EE (λ) x I (λ)	Negative Control		1% ACTS		3% ACTS		5% ACTS		Positive Control	
		Abs. (λ)	EExIx Abs	Abs. (λ)	EExIx Abs	Abs. (λ)	EExIx Abs	Abs. (λ)	EExIx Abs	Abs. (λ)	EExIx Abs
290	0.015	0.436	0.00654	0.572	0.00858	0.873	0.013095	0.947	0.014205	2.146	0.03219
295	0.0817	0.348	0.0284316	0.411	0.0335787	0.752	0.0614384	0.914	0.0746738	2.249	0.1837433
300	0.2874	0.295	0.084783	0.483	0.1388142	0.758	0.2178492	0.831	0.2388294	1.925	0.553245
305	0.3278	0.319	0.1045682	0.462	0.1514436	0.601	0.1970078	0.845	0.276991	1.928	0.6319984
310	0.1865	0.289	0.0538985	0.408	0.076092	0.578	0.107797	0.815	0.1519975	1.881	0.3508065
315	0.0839	0.264	0.0221496	0.318	0.0266802	0.549	0.0460611	0.807	0.0677073	1.769	0.1484191
320	0.018	0.202	0.003636	0.367	0.006606	0.421	0.007578	0.742	0.013356	1.687	0.030366

Total	1	0.3040069	0.4417947	0.6508265	0.83776	1.9307683
Multiplication with Correction Factor (10)		SPF 3.04±0.04	SPF 4.42±0.06	SPF 6.51±0.09	SPF 8.38±0.11	SPF 19.31 ±0.24

CONCLUSION

Based on the results and findings of the study, *Artocarpus camansi* fruit peel is a good source of phenolic compound that is physically stable when incorporated with topical serum excipients. Likewise, the formulated 5% topical serum showed potential antibacterial and anti-inflammatory activities. Consequently, the sun protection factor value can protect medium and dark skin for one hour and two hours respectively.

RECOMMENDATION

To provide future direction for the study, the researchers recommended that further testing on the increased concentration of *A. camansi* in the serum be conducted to improve the photoprotective activity as reflected in the SPF value. Likewise, the researchers would like to recommend that pharmacological testing be conducted to assess the safety of the serum.

TRANSLATIONAL RESEARCH

This study investigates the antibacterial, anti-inflammatory, and photoprotective properties of *Artocarpus camansi* topical serum, aiming to connect laboratory discoveries with real-world cosmeceutical applications. The findings of the study could be shared through a journal article for international publications and other media to ensure effective information dissemination. This research aims to utilize the bioactive compounds found in Artocarpus camansi to create a new plant-based dermatological serum that targets common skin issues and enhances skin health. The results are anticipated to guide the development of affordable, sustainable skincare products that can benefit people in both urban and rural areas. By working alongside clinicians and industry partners, this study highlights its potential to positively impact public health and promote the use of natural compounds in therapeutic applications.

Author Contribution: *Christine Joy N. Caballero-Blazo*: Primary Author:(Conceptualized the research study, Carried out the experiment, Organized and managed data, Analyzed results, Drafted the initial manuscript)., *Richie G. Bayuran*: Secondary author:(Conceptualized the research study, Approved the research methods, Analyzed results, Reviewed and edited the manuscript, Supervised the entire research study, Assisted the plagiarism checking and AI detection).
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