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Original Article

Sunscreen Activity Assays of an Emulgel Formulation Containing Nanoencapsulated *Ipomoea batatas* L. (Antin-3 Variety) Leaf Extract

Uji Aktivitas Tabir Surya dari Formula Emulgel yang Mengandung Nanokapsul Ekstrak Daun Ubi Jalar Ungu (*Ipomoea batatas* (L.)) Varietas Antin-3

Damaranie Dipahayu[1]*, Daffa Sachio Adenka[2], Jefri Ilyasa Srianto[2], Novita Dwi Astutik[2]

[1]Department of Pharmaceutical Technology, Faculty of Military Pharmacy, Universitas Pertahanan Indonesia, IPSC Sentul District, Sukahati, Citeureup, Bogor, West Java, Indonesia 16810

[2]Akademi Farmasi Surabaya, Jl. Ketintang Madya No.81, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60232 Indonesia

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Antin-3 Nanocapsule, Emulgel, Erythema, Pigmentation, SPF.

Abstract

Flavonoids in the purple sweet potato leaf extract (*Ipomoea batatas* (L.)) variety Antin-3 (Antin-3 extract) demonstrate effectiveness as natural sunscreen agents. Flavonoids are characterized by their large molecular weight and their susceptibility to degradation by light, high temperatures, and external environmental factors. Therefore, modification of the Antin-3 extracts through nanoencapsulation using chitosan and NaTPP is necessary to reduce particle size and protect the flavonoids, allowing them to remain longer in the skin layers and provide optimal sunscreen protection. This study aimed to formulate nanoencapsulated Antin-3 extract into emulgel sunscreen preparations and evaluate its sunscreen activity through SPF, erythema, and pigmentation values. The tested samples consisted of a base (control) and nanoencapsulated Antin-3 extract at concentrations of 0.3%, 0.6%, and 0.9%, labeled as Base, F1, F2, and F3, respectively. The physical characterization results showed pH values of 6.39 ± 0.04; 5.98 ± 0.28; 5.62 ± 0.25; and 5.3 ± 0.42 (sig. 0.027 < 0.05), and spreadability values of 5.91 ± 0.17; 5.89 ± 0.15; 6.08 ± 0.31; and 6.28 ± 0.16 cm^2 (sig. 0.266 > 0.05). The SPF values were 7.48 ± 0.01; 21.03 ± 0.03; 38.02 ± 0.10; and 38.29 ± 0.07 (sig. 0.00 < 0.05). The base formulation was categorized as having weak protection, the 0.3% Antin-3 emulgel provided moderate protection, while the 0.6% and 0.9% formulations were classified as offering high protection. All emulgel sunscreen formulations demonstrated the ability to protect the skin from redness and pigmentation caused by UV exposure. These findings highlight the potential of nanoencapsulated Antin-3 extract as a sustainable, plant-based alternative to synthetic sunscreen agents, contributing to safer and more eco-friendly photoprotection solutions.

Kata Kunci:
Emulgel, Erythema, Nanokapsul Antin-3, Pigmentasi, SPF.

Abstrak

Flavonoid dalam ekstrak daun ubi jalar ungu (*Ipomoea batatas* (L.)) varietas Antin-3 (ekstrak Antin-3) terbukti efektif sebagai agen tabir surya alami. Flavonoid memiliki karakteristik berat molekul yang besar dan rentan terhadap degradasi akibat cahaya, suhu tinggi, dan faktor lingkungan eksternal. Oleh karena itu, modifikasi ekstrak Antin-3 melalui nanoenkapsulasi menggunakan kitosan dan NaTPP diperlukan untuk memperkecil ukuran partikel dan melindungi flavonoid, sehingga dapat bertahan lebih lama di lapisan kulit dan memberikan perlindungan tabir surya yang optimal. Penelitian ini bertujuan untuk memformulasikan ekstrak Antin-3 yang dienkapsulasi dalam bentuk nano ke dalam sediaan emulgel tabir surya serta mengevaluasi aktivitas tabir surya melalui nilai SPF, eritema, dan pigmentasi. Sampel uji terdiri dari basis (kontrol) dan ekstrak Antin-3 nanoenkapsulasi dengan konsentrasi 0,3%, 0,6%, dan 0,9%, masing-masing diberi label Basis, F1, F2, dan F3. Hasil karakterisasi fisik menunjukkan nilai pH sebesar 6,39 ± 0,04; 5,98 ± 0,28; 5,62 ± 0,25; dan 5,3 ± 0,42 (sig. 0,027 < 0,05), serta nilai daya sebar sebesar 5,91 ± 0,17; 5,89 ± 0,15; 6,08 ± 0,31; dan 6,28 ± 0,16 cm^2 (sig. 0,266 > 0,05). Nilai SPF masing-masing adalah 7,48 ± 0,01; 21,03 ± 0,03; 38,02 ± 0,10; dan 38,29 ± 0,07 (sig. 0,00 < 0,05). Formulasi basis dikategorikan memiliki perlindungan lemah, emulgel Antin-3 0,3% memberikan perlindungan sedang, sedangkan formulasi 0,6% dan 0,9% diklasifikasikan memiliki perlindungan tinggi. Semua formulasi emulgel tabir surya menunjukkan kemampuan melindungi kulit dari kemerahan dan pigmentasi akibat paparan sinar UV. Temuan ini menegaskan potensi ekstrak Antin-3

Correspondence:
Damaranie Dipahayu
dipahayudamaranie@gmail.com

nanoenkapsulasi sebagai alternatif tabir surya berbasis tanaman yang aman, ramah lingkungan, dan berkelanjutan untuk menggantikan agen sintetis.

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INTRODUCTION

Ultraviolet (UV) radiation from sunlight comprises UVA (320–400 nm), UVB (290–320 nm), and UVC (200–290 nm) wavelengths. Prolonged UV exposure can cause erythema, hyperpigmentation, photoaging, and increase the risk of skin cancer.[1] Erythema, if untreated, may progress to pigmentation, while deeper UV penetration exacerbates carcinogenic risk. Sunscreens remain one of the most effective strategies for photoprotection.[2]

Growing concerns over the safety and environmental impact of synthetic UV filters have driven interest in natural alternatives with antioxidant and photoprotective properties. Purple sweet potato (Ipomoea batatas L.) leaves, particularly the Antin-3 variety, are rich in polyphenols and flavonoids. The extract contains 16.98 ± 0.77% flavonoids and 4.83 ± 0.07% polyphenols when extracted with 70% ethanol. At 900 ppm, Antin-3 extract demonstrates an SPF of 31.71 and exhibits strong antioxidant activity (IC_{50} = 47.99 ppm), approximately half that of vitamin C (20.18 ppm)[3] Despite these promising properties, incorporating Antin-3 extract into an emulgel sunscreen reduced its SPF to 6.5.[4] Emulgels—oil-in-water emulsions combined with a gel base—offer advantages such as improved spreadability, enhanced skin feel, and better solubility for hydrophilic actives.[4]

The reduction in SPF is attributed to the instability of polyphenols and flavonoids, which are prone to oxidation and degradation under environmental stressors such as heat and light. Encapsulation in biocompatible carriers, such as chitosan–sodium tripolyphosphate (NaTPP) nanoparticles, can enhance stability and skin penetration. [5] Chitosan, a biodegradable polysaccharide, forms nanoparticles via ionic gelation with NaTPP, creating a protective matrix for active compounds.[6] Nanoencapsulated Antin-3 prepared at a 1:5:1 ratio (extract : chitosan : NaTPP) demonstrated antioxidant activity (IC_{50} = 48.67 ppm) comparable to the crude extract.[7]

This study aimed to formulate sunscreen emulgels containing nanoencapsulated Antin-3 at concentrations of 0.3%, 0.6%, and 0.9%, and to evaluate their SPF values and protective effects against erythema and pigmentation.

RESEARCH METHOD

Tools. The tools used in this study were analytical balance (OHAUS-PA214), Spectrophotometer UV-Vis (Thermo Genesys 102), Centrifuge (PCL-03), Magnetic stirrer (Scilogex), mortar, stamper, beaker glass, spatula, watch glass.

Materials. Antin-3 purple sweet potato leaves were obtained from BALITKABI, Malang. Nanocapsules of Antin-3 extract were prepared at the Pharmaceutical Laboratory, Pharmacy Academy, Surabaya. Emulgel excipients included olive oil (cosmetic grade), cethyl alcohol (pharmaceutical grade), Tween 80 (pharmaceutical grade), Span 80 (pharmaceutical grade), 2-propanol (pharmaceutical grade), Carbopol 940 (pharmaceutical grade), propylene glycol (pharmaceutical grade), triethanolamine (TEA; pharmaceutical grade), methylparaben (nipagin; pharmaceutical grade), propylparaben (nipasol; pharmaceutical grade) sourced from Muda Berkah Jogja, and CO_2-free demineralized water (aqua demineralisata) obtained from Brataco, Surabaya.

Formulation and Preparation of Emulgel Sunscreen

Emulgel was prepared according to the formulation presented in **Table 1**. The gelling agent was prepared by dispersing Carbopol 940 into one-third of the total CO_2-free demineralized water and stirring slowly until homogeneous. Triethanolamine (TEA) was added dropwise to neutralize the dispersion, which was then allowed to hydrate for 30 minutes. The oil phase, consisting of olive oil, Span 80, and cethyl alcohol, was

melted in a water bath at 70 °C. The aqueous phase, comprising Tween 80, methylparaben, propylparaben, and the remaining water, was heated to the same temperature. The aqueous phase was gradually added to the oil phase under continuous stirring using a magnetic stirrer until an emulsion formed and cooled to 35 °C. The hydrated gelling agent was then incorporated into the emulsion, followed by the addition of propylene glycol, to obtain the emulgel base. Antin-3 extract nanocapsules, pre-dispersed in propylene glycol (1:1), were incorporated into the emulgel base at concentrations of 0.3%, 0.6%, and 0.9% to produce the final sunscreen emulgels.[8]

Table 1. Emulgel Sunscreen Formulation

Material	Function	Base	F1	F2	F3
Nanocapsule Antin-3 Extract	Active Ingredients	-	0.3	0.6	0.9
Olive oil	Oily base	10	10	10	10
Cethyl alcohol	Viscosity increasing agent	2.5	2.5	2.5	2.5
Span 80	Emulgator	8.4	8.4	8.4	8.4
Tween 80	Emulgator	5.6	5.6	5.6	5.6
Carbopol 940	Gelling agent	2	2	2	2
TEA	Alkalizing agent	2	2	2	2
Propylene glycol	Humectant	10	10	10	10
Methylparaben	Preservatives	0.8	0.8	0.8	0.8
Propylparaben	Preservatives	0.02	0.02	0.02	0.02
Aquadest CO_2 Free	Solvent	ad 100	ad 100	ad 100	ad 100

Emulgel sunscreen characterization

Organoleptic characteristic

The organoleptic evaluation assessed the sensory characteristics of the emulgel, including texture, color, and odor.[9]

pH value characteristic

The pH of the emulgel formulations was measured using a calibrated pH meter. Approximately 1 g of each sample was dispersed in 10 mL of CO_2-free demineralized water and mixed until homogeneous. The electrode was immersed in the dispersion, and the pH value was recorded once the reading stabilized.[8]

Spreadibilty characteristic

Spreadability was evaluated using the parallel plate method. Approximately 0.5 g of emulgel was placed on a glass plate and covered with another plate. Incremental weights of 50, 100, 150, and 200 g were applied sequentially, each for 60 seconds. The diameter of the spread was measured in multiple directions, and the mean value was recorded for analysis.[8]

In vitro SPF value, % erythema and % pigmentation measurement

Samples of Antin-3 leaf extract nanocapsule emulgel sunscreen (1,000 mg) were prepared at concentrations of 0.3%, 0.6%, and 0.9%. Each sample was dissolved in 2-propanol in a beaker, transferred to a 10 mL volumetric flask, and diluted to the mark with 2-propanol.[9] The solution was then filtered through filter paper into a clean beaker. An aliquot was placed in a cuvette and adjusted to the appropriate volume. UV-Vis spectrophotometric analysis was performed using 2-propanol as the blank.[10] Absorbance was measured across the wavelength range of 290–320 nm at 5 nm intervals to calculate the Sun Protection Factor (SPF). Transmission values within this range were recorded to determine the percentage of erythema protection. Additionally, transmittance was measured between 323–373 nm to calculate the percentage of pigmentation protection.[11]

SPF Value equation:

$$SPF = CF \times \sum_{290}^{320} EE(\lambda) \times I(\lambda) \times abs(\lambda) \quad \text{.......} (1)$$

Description:

EE : Erythemal effect spectrum

I : Solar intensity spectrum

Abs : Absorbance of sunscreen product
CF : Correction factor (=10)

In vitro % erythema and % pigmentation

$$\%Te = \frac{Ee}{\Sigma Fe} = \frac{\Sigma(TxFe)}{\Sigma Fe} \quad \text{..... (2)}$$

$$\%Tp = \frac{Ep}{\Sigma Fp} = \frac{\Sigma(TxFp)}{\Sigma Fp} \quad \text{..... (3)}$$

Description:
% Te : percent erythema transmission value
% Tp : percent pigmentation transmission value
Ee : ∑(T x Fe)
Ep : ∑(T x Fp)

Statistical analysis

Data was analyzed using SPSS software. The Shapiro–Wilk test was applied to assess the normality of data distribution, while Levene's test was used to evaluate homogeneity of variances. When both assumptions were satisfied ($p \geq 0.05$), the data were further analyzed using one-way analysis of variance (ANOVA).

RESULT AND DISCUSSION

The organoleptic characteristics, pH values, and spreadability of the samples are presented in **Table 2**. Organoleptic evaluation showed that increasing extract concentration resulted in a darker brown color and a stronger extract aroma. The acceptable pH range for topical preparations is 4.5–5.5.[12] The base and emulgel formulations containing 0.3% and 0.6% nanocapsules exhibited neutral pH values, whereas the 0.9% formulation met the skin pH requirement. One-way ANOVA indicated significant differences in pH among all samples ($p = 0.027 < 0.05$).

The recommended spreadability range for emulgel is 2.58–5.00 cm.[13] None of the formulations met this criterion; however, a wider spread area is desirable to ensure uniform skin coverage.[14] Antin-3 extract nanocapsules exhibit acidic properties that influence the neutral pH of the emulgel base. Phenolic compounds—of which more than 8,000 have been identified—contain at least one aromatic ring and one or more hydroxyl groups. The delocalized electron system of the benzene ring stabilizes the phenoxide anion formed upon proton dissociation.[15] The acidic environment in Carbopol-based gels must be neutralized with triethanolamine (TEA) to optimize gel formation.[16] Increasing the concentration of Antin-3 nanocapsules reduced formulation viscosity, resulting in a thinner consistency. One-way ANOVA showed no significant differences in spreadability among samples ($p = 0.266 > 0.05$). For sunscreen formulations, ease of application and adequate coverage are essential to ensure effective facial protection.

Table 2. Evaluation results of basis and emulgel nanocapsule of Antin-3 extract sunscreen

Sample	Organoleptic	pH value	Spreadability
Base	Thick, white, odorless	6.39 ± 0.04	5.91 ± 0.17
F1	Thick, cloudy white, mild extract odor	5.98 ± 0.28	5.89 ± 0.15
F2	Thick, whitish-brown, mild extract odor	5.62 ± 0.25	6.08 ± 0.31
F3	Thick, whitish-brown, normal extract odor	5.3 ± 0.42	6.28 ± 0.16

The results for SPF, percentage erythema protection, and percentage pigmentation protection are presented in **Table 3**. Sunscreen effectiveness is primarily indicated by the Sun Protection Factor (SPF), which represents the ratio of the minimal erythema dose (MED) on protected skin to that on unprotected skin. MED is defined as the lowest UV radiation dose or exposure time required to produce erythema. This value reflects

the duration of protection provided by the active ingredients in the sunscreen, where an SPF of 1 is approximately equivalent to 15 minutes of protection.[17]

Table 3. Result of SPF Value

Sample	SPF Value				Sunscreen category
	Rep 1	Rep 2	Rep 3	Average	
Base	7.47	7.48	7.49	7.48 ± 0.01	Low (SPF 2-15)
F1	21.00	21.04	21.07	21.03 ± 0.03	Middle (SPF 16-29)
F2	37.89	38.03	38.13	38.02 ± 0.10	High (SPF 30-50)
F3	38.33	38.42	38.24	38.29 ± 0.07	High (SPF 30-50)

The statistical analysis of SPF values is presented in **Table 4**. The SPF data for the four samples were normally distributed and homogeneous. One-way ANOVA revealed a significant difference among the groups ($p < 0.05$). The emulgel base exhibited an SPF of 7.48, classified as low protection (SPF 2–15) and considered ineffective for adequate sun protection. The emulgel containing 0.3% nanocapsules demonstrated moderate protection (SPF 16–29), while formulations with 0.6% and 0.9% nanocapsules achieved high protection (SPF 30–50), comparable to formulations containing 9% extract. In tropical regions such as Indonesia, sunscreens with SPF ≥30 are recommended.[18] The high SPF values observed are attributed to the polyphenolic compounds in Antin-3 extract nanocapsules, which absorb UV radiation and neutralize reactive oxygen species.[18]

Table 4. Statistical result of SPF Value

Statistic Test	Sig Requirements	Sig result	Conclusions
Normality Test	> 0.05	0.12	Data normally distributed
Homogeneity Test	> 0.05	0.16	Data homogenously distributed
One Way Anova	< 0.05	0.00	Significant difference

The percentage erythema values are presented in **Table 5**. The data were normally distributed and homogeneous ($p > 0.05$). One-way ANOVA followed by Tukey's HSD test revealed significant differences between the base formulation and the emulgel containing 0.3% Antin-3 extract nanocapsules compared to formulations with 0.6% and 0.9% nanocapsules ($p < 0.05$). No significant difference was observed between the 0.6% and 0.9% formulations ($p > 0.05$). Polyphenols in Antin-3 extract reduce erythema by scavenging reactive oxygen species (ROS) and suppressing the inflammatory cascade responsible for redness and swelling.[20] UVB radiation is a major contributor to sunburn, causing erythema and irritation of the skin.[20]

Table 5. Result of % erythema value

Sample	% Erythema				Sunscreen category
	Rep 1	Rep 2	Rep 3	Average	
Base	9.91	9.93	9.97	9.93 ± 0.02	Suntan (6-12)
F1	0.41	0.41	0.40	0.41 ± 0.00	Sunblock (<1)
F2	0.01	0.01	0.01	0.01 ± 0.00	Sunblock (<1)
F3	0.01	0.01	0.01	0.01 ± 0.00	Sunblock (<1)

The percentage pigmentation values are presented in **Table 6**. The data were normally distributed and homogeneous ($p > 0.05$). One-way ANOVA followed by Tukey's HSD test revealed a statistically significant difference ($p < 0.05$) among the base formulation and the emulgel sunscreens containing Antin-3 extract nanocapsules at concentrations of 0.3%, 0.6%, and 0.9%, in terms of pigmentation protection. There is a known relationship between erythema and pigmentation, as erythema-induced inflammation can trigger biological processes that lead to hyperpigmentation. Antin-3 extract nanocapsules provide dual protection by reducing both erythema and pigmentation through their antioxidant activity.[21]

Table 6. Result of % pigmentation value

Sample	% Erythema				Sunscreen category
	Rep 1	Rep 2	Rep 3	Average	
Base	43.00	43.18	43.34	43.17 ± 0.14	Extra protection (42-86)
F1	7.72	7.80	7.78	7.77 ± 0.04	Sunblock (3-40)
F2	2.10	2.09	2.09	2.09 ± 0.00	Sunblock (3-40)
F3	1.13	1.14	1.14	1.14 ± 0.00	Sunblock (3-40)

The base formulation exhibited erythema values within the suntan category (6–12%) and pigmentation values within the extra protection category (42–86%). This indicates that while the base formulation offers some protection against pigmentation, it is insufficient to prevent erythema or skin irritation caused by UV exposure. Pigmentation is primarily triggered by UVB radiation (280–315 nm), which has a shorter wavelength than UVA (315–400 nm). The emulgel base contains olive oil, which provides partial protection against shortwave radiation but is not effective against longer wavelengths.[22] In contrast, emulgel formulations containing Antin-3 extract nanocapsules at concentrations of 0.3%, 0.6%, and 0.9%, as well as the formulation with 9% extract, demonstrated total sunblock protection, effectively preventing both erythema and pigmentation.[23] Purple sweet potato (*Ipomoea batatas*) leaves, the source of Antin-3 extract, are rich in flavonoids, which exhibit anti-inflammatory activity through multiple pathways, including inhibition of cyclooxygenase (COX) and lipoxygenase enzymes, suppression of leukocyte accumulation, inhibition of neutrophil degranulation, and reduction of histamine release. These mechanisms contribute to the extract's ability to mitigate UV-induced inflammation and pigmentation.[24] To further illustrate the comparative duration of skin protection, **Figure 1** presents the estimated protection times for each formulation.

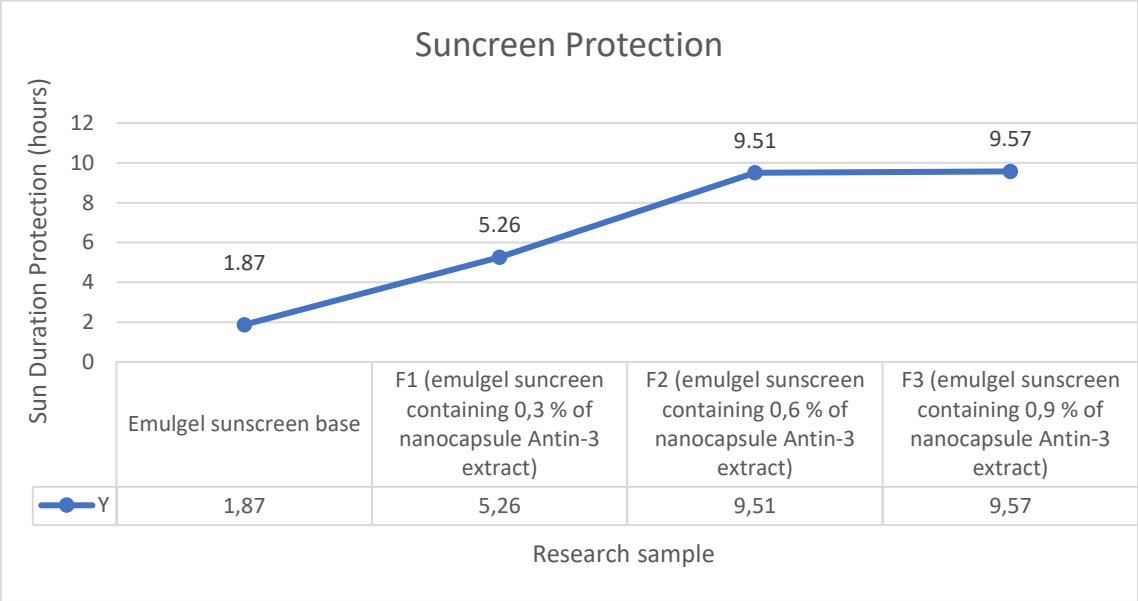

Figure 1. Sun duration protection of samples

As shown in Figure 1, increasing the concentration of nanocapsules enhanced skin protection against UV radiation. This effect is attributed to the higher flavonoid content in Antin-3 extract, which increases light absorption at specific wavelengths, thereby elevating absorbance values.[26] The 0.3% formulation provided only moderate protection with a shorter duration of UV defense, indicating that the conjugated double bonds of polyphenols and flavonoids at this concentration were insufficient for effective photoprotection.[27] In contrast, formulations containing 0.6% and 0.9% Antin-3 extract nanocapsules exhibited comparable durations of protection, although statistical analysis revealed a significant difference between them. Both concentrations effectively prevented erythema and completely inhibited skin pigmentation. These findings suggest that a 0.6% concentration of Antin-3 extract nanocapsules is adequate to protect against erythema and pigmentation through UV absorption and anti-inflammatory mechanisms.[20,21] Notably, the 0.3% difference between 0.6% and 0.9% concentrations resulted in only a 0.06-hour (3.6-minute) difference in protection time, implying that higher concentrations may offer minimal additional benefit. Further studies are warranted to determine whether this marginal increase in protection is clinically meaningful and to explore potential differences in antioxidant and anti-inflammatory activity between the two concentrations.

CONCLUSION

All emulgel sunscreen formulations containing Antin-3 extract nanoencapsulated (0.3%, 0.6%, and 0.9%) met the required physicochemical standards, including organoleptic properties, pH, and spreadability. Variations in nanocapsule concentration significantly influenced UV protection performance. Formulations with 0.6% and 0.9% Antin-3 extract nanocapsules demonstrated high photoprotective efficacy, providing estimated protection durations of 9.51 and 9.57 hours, respectively. In contrast, the 0.3% formulation offered only moderate protection, with a duration of 5.26 hours. These findings indicate that a 0.6% concentration is sufficient to achieve prolonged UV protection, while increasing the concentration to 0.9% yields minimal additional benefit. Further studies are recommended to evaluate whether the slight increase in protection time at higher concentrations is clinically significant and to explore potential differences in antioxidant and anti-inflammatory activity.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this manuscript.

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