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Formulation and Stability Evaluation of Sunscreen Cream: Utilization of Methyl Cinnamate Isolate from *Alpinia galanga* L. Rhizome as a Photoprotective Agent

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Abstract

Methyl cinnamate isolate is an aromatic ester compound with a conjugated chromophore system capable of absorbing UV-B radiation, making it a promising candidate for sunscreen formulations. This study aimed to determine the optimum concentration of methyl cinnamate isolate based on its sun protection factor (SPF) and to develop a sunscreen cream with satisfactory physical stability. Methyl cinnamate isolate solutions were prepared at concentrations of 1000, 2000, 3000, 4000, and 5000 ppm and screened for SPF activity. The concentration yielding the highest SPF value was incorporated into cream formulations containing different stearic acid concentrations as an emulsifier (F1: 8% w/w and F2: 10% w/w). The resulting formulations were assessed for SPF, physical characteristics during 28 days of storage at room temperature, microbiological quality, and methyl cinnamate content under accelerated stability conditions (40 ± 2°C and 75 ± 5% RH). The isolate at 5000 ppm (0.5%) exhibited the highest SPF value of 33.49, corresponding to the ultra-protection category. Both formulations maintained acceptable physical characteristics throughout the storage period. At day 28, SPF values were 13.87 for F1 and 17.02 for F2, with F2 remaining within the ultra-protection category. After three months of accelerated stability testing, methyl cinnamate content was 47.62% in F1 and 68.32% in F2. Microbiological evaluation also revealed contamination based on total plate count and yeast–mold count analyses. These findings indicate that methyl cinnamate isolate has potential as a sunscreen active ingredient; however, further formulation optimization and preservative incorporation are required to improve chemical stability and microbiological quality.

Keywords: cream, methyl cinnamate, SPF (sun protection factor), sunscreen.

Introduction

Sunlight exposure, particularly to ultraviolet (UV) radiation, provides several health benefits; however, excessive and prolonged exposure can also cause significant skin damage, especially in individuals who frequently engage in outdoor activities. Chronic UV exposure may damage epidermal tissues, induce oxidative stress through free radical generation, and trigger skin irritation, inflammation, and premature aging.[1] Therefore, effective skin protection is essential and can be achieved through physical barriers and the application of topical sunscreens.[2]

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Sunscreens are generally classified into two categories based on their mechanism of action: chemical sunscreens, which absorb UV radiation and convert it into heat through conjugated chromophore systems; and physical sunscreens, which reflect or scatter UV radiation from the skin surface.[3] Chemical sunscreens are typically colorless and cosmetically elegant, whereas physical sunscreens provide broader-spectrum protection but are often less preferred because of their whitening effect on the skin.[4] Among various dosage forms, creams remain one of the most widely used sunscreen formulations due to their ease of application, good spreadability, and user acceptability.[3]

Greater galangal (*Alpinia galanga* L.), a rhizomatous plant belonging to the Zingiberaceae family, is a rich source of bioactive compounds, including flavonoids, essential oils, and methyl cinnamate. These constituents exhibit diverse biological activities, such as antibacterial, antifungal, antiviral, and antioxidant properties.[5] Methyl cinnamate, an ester derivative of cinnamic acid, is produced via an esterification reaction with methanol.[6] Methyl cinnamate, a cinnamic acid ester naturally abundant in greater galangal, possesses a conjugated double-bond system capable of absorbing UV radiation through resonance stabilization.[7] This characteristic suggests its potential application as a natural sunscreen active ingredient.

Although the photoprotective potential of cinnamate derivatives has been widely reported, studies investigating isolated methyl cinnamate from *A. galanga* and its incorporation into sunscreen cream formulations remain limited. Furthermore, information regarding the physical stability, active-content stability, and microbiological quality of methyl cinnamate-based sunscreen creams is still scarce. Therefore, this study was conducted to address these knowledge gaps by developing and evaluating a sunscreen cream containing methyl cinnamate isolate obtained from greater galangal.

The study involved SPF determination of methyl cinnamate isolate, development of sunscreen cream formulations containing different stearic acid concentrations (8% and 10% w/w), evaluation of physical characteristics during 28 days of storage at room temperature, accelerated stability testing of methyl cinnamate content under 40 ± 2°C and 75 ± 5% RH conditions, and microbiological assessment through Total Plate Count (TPC) and Yeast–Mold Count (YMC) analyses. Stearic acid concentration was selected as the primary formulation variable due to its important role in emulsion formation, viscosity development, and cream stability.[8]

Method

Tool

Hot plate (Thermo Scientific Cimarec+), analytical balance (Ohaus®), incubator (Memmert® IN110), UV-Vis spectrophotometer (Genesys 10S), micropipette with tips, Brookfield LV viscometer, autoclave (GEA® LS-50LJ), Pyrex® glassware, climatic chamber (Capromax®), digital pH meter (Mettler Toledo), colony counter (Rocker® Galaxy 230), IKA mixer (Ministar 20), centrifuge (Hettich® EBA 20), parchment paper, cotton, and gauze.

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Material

Methyl cinnamate isolate (STFI-LKIH), stearic acid (Oleochemicals Industry), glycerin (PT. Wilmar), cetyl alcohol, methyl paraben, propyl paraben, triethanolamine, Tween 80, rose oil, distilled water, 96% ethanol, 0.9% NaCl, methylene blue solution (PT. Dwilab), pro analysis methanol (Merck®), NA and PDA media (Merck®).

Procedure

Determination of Methyl Cinnamate SPF Value

SPF value determination involved dissolving 500 mg methyl cinnamate isolate in pro analysis 96% ethanol to 100 mL in a volumetric flask as a stock solution. The stock was diluted to concentrations of 1000, 2000, 3000, 4000, and 5000 ppm. Absorbance of each dilution was measured using a UV-Vis spectrophotometer at 290–320 nm (5 nm intervals) with 96% ethanol as blank.[8] SPF values were calculated using the following equation:

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

Equation Parameters
CF: Correction Factor (= 10)
EE: Erythema Effect Spectrum
I: Solar Intensity Spectrum
Abs: Sample Absorbance

Sunscreen Cream Formulation

Sunscreen cream was formulated using the two-phase fusion method, melting the oil phase (stearic acid, cetyl alcohol, propyl paraben) at 70°C and heating the aqueous phase (glycerin, triethanolamine, methyl paraben, distilled water) to the same temperature. Both phases were gradually combined and homogenized using a mixer at 1000 rpm for 15 minutes, followed by addition of remaining distilled water to form a homogeneous emulsion. Rose oil was incorporated with thorough stirring, followed by addition of methyl cinnamate isolate to the cream base, yielding the final homogeneous preparation.[9,10] The cream formulation composition is presented in Table 1.

Table 1. Methyl Cinnamate Isolate Sunscreen Cream Formulation

Ingridients	Concentration (%)			Function
	F0	F1	F2	
Methyl Cinnamate Isolate	-	0.5	0.5	Active Ingredient
Stearic Acid	8	8	10	Emulsifying Agent
Cetyl Alcohol	1	1	1	Stiffening Agent
Glycerin	15	15	15	Humectant
Triethanolamine	0.5	0.5	0.5	Emulsifying Agent
Methyl Paraben	0.1	0.1	0.1	Antimicrobial agent
Propyl Paraben	0.05	0.05	0.05	Antimicrobial agent
Oleum Rosae	qs	qs	qs	Fragrance
Purified Water ad	100	100	100	Solvent/vehicle

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SPF Value Determination of Cream

Sample cream 100 mg dissolved in pro analysis 96% ethanol to 10 mL mark in volumetric flask (10 ppm concentration). 1 mL aliquot absorbance measured by UV-Vis spectrophotometer (λ 290–320 nm, 5 nm intervals), using 96% ethanol as blank.[11]

Storage Stability Evaluation

Sunscreen cream evaluated and observed on storage days 0, 7, 14, 21, and 28 at room temperature.[12]

Organoleptic Evaluation

Organoleptic assessment involved visual observation of morphology, color, and odor from ~0.5 g sample uniformly spread on a glass slide.[12]

pH Test

pH measurement conducted using a pH meter calibrated with standard buffers (pH 4.0, 7.0, 9.0). Semi-solid electrode immersed in cream; pH recorded. Quality sunscreen cream pH range: 4.5–8.0 (SNI 16-4399-1996).[12]

Homogeneity Test

Formulation thinly applied and spread on a glass slide. Homogeneity acceptable if no significant color/texture variation (absence of coarse particles or clumps).[13,14]

Viscosity Test

Viscosity measured using Brookfield viscometer spindle #4 at 6 rpm. Ideal viscosity range: 2,000–50,000 cps.[14,15]

Spreadability and Adhesion Tests

One gram of cream is applied to the testing device under a 250 g weight for one minute before measurement, with optimal spreadability falling within 5–7 cm; for adhesion testing, 1 g cream is placed on the apparatus under a 250 g load for 3 minutes and the surface separation time recorded as adhesion strength, where good formulations exceed 4 seconds.[14,16]

Emulsion Type Test

Emulsion type is determined using methylene blue staining by applying a cream sample on a glass slide with a methylene blue droplet, where uniform blue color indicates O/W emulsion and uneven distribution indicates W/O.[13]

Determination of Methyl Cinnamate Content During Accelerated Stability Testing

Active ingredient assay served as the chemical stability parameter in sunscreen cream stability testing conducted in a climatic chamber at 40±2°C and 75±5% RH for 3 months with analysis at 0, 1, 2, and 3-month intervals.[17] Methyl Cinnamate Assay Procedure by UV-Vis spectrophotometry at λ_max 261 nm. 200 mg of cream dissolved in pro analysis methanol to a 10 mL volume, then centrifuged at 3000 rpm for 10 minutes, with supernatant absorbance measured and content determined from the calibration curve.[18]

TPC and YMC Testing of Sunscreen Cream

Preparation involved equipment sterilization using an autoclave at 121°C for 15 minutes, followed by NA media preparation at 2 g per 100 mL and PDA media at 2.25 g per 100 mL, both sterilized accordingly.[19,20] Sample Preparation: One gram of cream

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was mixed with 1 mL Tween 80 and 0.9% NaCl, diluted to 10 mL for a 10^{-1} dilution, then serially diluted to 10^{-5} by transferring 1 mL into 9 mL of 0.9% NaCl.[21] Total Plate Count (TPC) testing utilized 10^{-1} and 10^{-2} dilutions, where 1 mL was pipetted into a Petri dish with 10 mL NA using the pour plate method, followed by homogenization and incubation at 37°C for 24 hours. Yeast and Mold Count (YMC) employed similar dilutions, with 1 mL added to 10 mL PDA, then incubated inverted at 37°C for 72 hours, and colony enumeration was conducted post-incubation for both parameters.[22,23]

Result

Figure 1 shows that the methyl cinnamate isolate sunscreen cream exhibits a semi-solid consistency, characteristic aroma, and white color.

Figure 1. Methyl cinnamate isolate sunscreen cream

Table 2 presents SPF evaluation results for methyl cinnamate isolate and sunscreen cream containing 0.5% isolate.

Table 2. SPF Values of Isolate and Sunscreen Cream

SPF Value of Methyl Cinnamate Isolate			SPF Value of Cream Formulation				
				Storage Day Observation			
Concentration (ppm)	SPF	Protection Category	Sampel	0	Protection Category	28	Protection Category
1000	31.09	Ultra	F0A	0.30	None	0	None
2000	32.54	Ultra	F0B	0.86	None	0	None
3000	33.29	Ultra	F1	16.34	Ultra	13.87	Maximum
4000	33.26	Ultra	F2	16.24	Ultra	17.02	Ultra
5000	33.49	Ultra					

Notes:
F1: Sunscreen cream formula with 8% stearic acid content.
F2: Sunscreen cream formula with 10% stearic acid content.
F0A: Base of Formula 1.
F0B: Base of Formula 2.

The sunscreen cream formulations were prepared using methyl cinnamate isolate at the optimum concentration determined from the preliminary SPF study. The selected concentration was 5000 ppm, equivalent to 0.5% (w/v), and was incorporated into all formulations. In addition to SPF determination, the formulations were evaluated for physical characteristics. The results are presented in Table 3.

Table 3. Physical Evaluation Results of Methyl Cinnamate Sunscreen Cream

Parameter	Formulation		
	F0	F1	F2
Organoleptic			
Morphology	Semi-solid	Semi-solid	Semi-solid
Color	White	White	White
Odor	characteristic	characteristic	characteristic
Homogenity	Homogeneous	Homogeneous	Homogeneous
pH	7.25	6.64	6.28
Viscosity (mPa·s)	46333	32333	38167
Spreadability (cm)	5	5	5
Adhesion (Second)	9.7	31.3	33.3
Emulsion Type	O/W	O/W	O/W

A 28-day storage evaluation was performed on each formula, with comprehensive results presented in Table 4.

Table 4. Physical Evaluation Results of Methyl Cinnamate Sunscreen Cream After 28 Days Storage

Parameter	Formulation		
	F0	F1	F2
Organoleptic			
Morphology	Semi-solid	Semi-solid	Semi-solid
Color	White	White	White
Odor	characteristic	characteristic	characteristic
Homogenity	Homogeneous	Homogeneous	Homogeneous
pH	7.95	7.86	8.14
Viscosity (mPa·s)	19333	21833	22000
Spreadability (cm)	5.4	5.5	5.5
Adhesion (Second)	17	18.7	25.3
Emulsion Type	O/W	O/W	O/W

After formulation evaluation, accelerated stability testing was conducted for 3 months at 40±2°C and 75±5% RH, with methyl cinnamate content assessed at 0, 1, 2, and 3 months, and results shown in Table 5.

Table 5. Methyl Cinnamate Content in Sunscreen Cream

Formulation	Content at Month -		
	1 (%)	2 (%)	3 (%)
F1	88.01	84.40	47.62
F2	97.60	89.72	68.32

Following content stability testing, TPC (ALT) and YMC (AKK) assays were performed; results are in Table 6.

Table 6. TPC and YMC Results of Sunscreen Cream

Formulation	Observation			
	TPC		YMC	
	10^{-1}	10^{-2}	10^{-1}	10^{-2}
F0	84×10^{-1}	213×10^{-2}	185×10^{-1}	235×10^{-2}
F1	11×10^{-1}	89×10^{-2}	164×10^{-1}	121×10^{-2}

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Discussion

Methyl cinnamate isolate was obtained from Lembaga Kekayaan Intelektual dan Hilirisasi (LKIH-STFI), Sekolah Tinggi Farmasi Indonesia, Bandung, Indonesia. Therefore, the isolation process was not conducted as part of this study. According to the Certificate of Analysis (CoA), the methyl cinnamate isolated from *Alpinia galanga* rhizomes exhibited a purity of 97%, as determined by HPLC using a reference standard. The isolate was subsequently evaluated for its photoprotective activity by determining the sun protection factor (SPF) using a UV–Vis spectrophotometer over the wavelength range of 290–320 nm at 5 nm intervals. SPF measurements were performed at concentrations of 1000, 2000, 3000, 4000, and 5000 ppm to identify the optimum concentration for formulation development. Table 2 demonstrates SPF values increasing proportionally with concentration, reflecting enhanced sunscreen protection. This effect stems from methyl cinnamate chromophores absorbing UV radiation through conjugated π-electron resonance, delivering superior skin protection against UV damage at higher concentrations.[7]

Methyl cinnamate concentration selected for cream formulation based on highest SPF value: 5000 ppm (equivalent to 0.5%). This concentration was formulated into 2 variants varying stearic acid as an emulsifying agent. Stearic acid (C18), a long-chain saturated fatty acid, serves as a primary cream base for ideal semi-solid consistency, an oil-phase emulsifier, a viscosity enhancer preventing oil-phase sedimentation, and a high-melting-point compound ensuring thermal stability. Post-formulation, SPF testing and physical evaluations were conducted.[24]

The SPF value of methyl cinnamate isolate decreased from 31–33 (pure form) to 16.34/16.24 in F1/F2 cream formulations on day 0, attributed to volumetric dilution within the O/W emulsion matrix, lipophilic partitioning into the oil phase, light scattering by microdroplets, and interactions with glycerin and triethanolamine that reduced effective concentration to approximately 52% of pure isolate. Formulations with high oil phase proportion and low stearic acid content exhibited significantly lower SPF values due to formation of less dense "liquid-like" emulsions, which diminished UV Mie scattering and caused excessive solubilization of methyl cinnamate, thereby suppressing the reservoir effect.

Stearic acid, triethanolamine (TEA), and cetyl alcohol were used as key excipients in the sunscreen cream formulations. Stearic acid and TEA interact to form an oil-in-water emulsifying system, while cetyl alcohol functions as a co-emulsifier and consistency-enhancing agent. These excipients contribute to emulsion stability, viscosity, and the overall physical characteristics of the cream. Therefore, variations in stearic acid concentration may influence the distribution and retention of methyl cinnamate within the formulation, potentially affecting the observed SPF values and stability during storage.[25]

The selection of stearic acid concentrations of 8% and 10% was based on previous studies demonstrating that these concentrations are commonly used in cream formulations and are capable of producing acceptable physical characteristics. This concentration range was chosen to evaluate the effect of increasing stearic acid concentration on the physical properties of the cream, including viscosity, spreadability, adhesiveness, and emulsion stability. The 8% concentration was selected as the lower limit expected to provide adequate viscosity and stability. In contrast, the 10% concentration was used to assess the impact of a higher stearic acid concentration on the physical characteristics of the formulation, thereby enabling the determination of the optimal formulation.[26]

Cream evaluation encompassed organoleptic properties, pH, homogeneity, viscosity, spreadability, adhesion, and emulsion type to ensure product quality, safety, and efficacy. Organoleptic assessment confirmed semi-solid consistency, characteristic odor, and white color. All analytical measurements were performed in

triplicate (n = 3), and the results were expressed as the mean. Table 3 and Figure 1 demonstrate stability maintenance throughout 28 days without parameter changes, indicating excellent organoleptic stability.

pH monitoring assessed cream acidity changes over 28 days. Per SNI 16-4399-1996, the ideal pH range 4.5–8.0 aligns with skin physiology to prevent irritation and dryness.[27] Table 4 reveals a general pH increase trend across formulations. F0 and F1 maintained the required range; F2 exceeded the standard. pH elevation is attributed to basic triethanolamine (pH ≈10.5) forming anionic soap with stearic acid (pH ≈8), where higher triethanolamine concentration elevates cream pH. Excessively alkaline pH causes skin dryness; overly acidic pH risks irritation. Thus, pH control is critical for formulation safety and user comfort.[15,28] Therefore, pH control constitutes a critical parameter ensuring formulation safety and user comfort.

Homogeneity testing assessed uniform ingredient dispersion in sunscreen cream. Tables 3 and 4 confirm all formulations remained homogeneous from day 0–28 storage—homogeneity was defined by uniform color/texture without coarse particles or clumps. Results indicate optimal oil-water phase fusion. Excellent homogeneity ensures uniform component distribution, yielding stable cream without phase separation or aggregation during storage.[10]

Viscosity measurement determined sunscreen cream consistency. SNI specifies an ideal range of 2,000–50,000 cps. Tables 3 and 4 confirm F0, F1, and F2 viscosities met standards both initially and throughout 28-day storage.[12] Results confirm formulation consistency remained stable without significant changes—optimal viscosity characterized by balanced cream texture (neither too thick nor thin), ensuring comfortable application. Primary influencing factors include mixing duration and composition, particularly stearic acid and cetyl alcohol—both function as thickening agents and emulsifiers, significantly increasing cream viscosity. Higher concentrations improve adhesion but reduce spreadability. Stearic acid is commonly paired with TEA, while cetyl alcohol stabilizes the emulsion. TEA combination forms anionic TEA stearate salt via neutralization, synergistically elevating pH, enhancing hydrophilic solubility, and generating electrostatic repulsion between O/W emulsion droplets for enhanced stability.[15,24,28]

Spreadability testing assessed cream application ease by measuring spread diameter under a standard load of 250 g. Table 4 confirms stable spreadability of 5.4–5.5 cm over 28 days, meeting 5–7 cm criteria. Optimal spreadability reflects balanced viscosity enabling uniform skin coverage without excessive yield stress. Stearic acid and cetyl alcohol enhance structural viscosity, while triethanolamine neutralization forms TEA-stearate, reducing interfacial tension for ideal spreadability index and long-term storage stability.[28]

Adhesion testing measured cream retention duration on skin with minimum standard >4 seconds, where longer adhesion time indicates enhanced active ingredient retention and prolonged skin efficacy.[15] Table 4 demonstrates all formulations satisfied adhesion requirements exceeding 4 seconds, with stability maintained throughout 28 days of storage, particularly F1 and F2, which exhibited superior performance averaging 15 to 33 seconds, facilitating maximum active ingredient absorption. Stearic acid and cetyl alcohol served as thickening agents producing solid consistency, while triethanolamine balanced viscosity to create adhesive yet readily absorbed cream characteristics, resulting in optimal formulation performance.[28]

Emulsion typing confirmed all three formulations, F0, F1, and F2, as stable O/W (oil-in-water) systems throughout 28-day storage, evidenced by uniform methylene blue dispersion in the continuous aqueous matrix. O/W emulsion preferred for superior skin application (optimal penetration, easy cleansing) and interfacial stability from TEA stearate as primary anionic emulsifier.[13]

Stability testing evaluated cream quality changes under storage conditions using a climatic chamber at 40±2°C and 75±5% RH for 3 months, assessing temperature, humidity, and light effects on active content to establish shelf life.[17] Analysis commenced with calibration curve construction in pro analysis methanol at λ_max 261 nm. Standard concentrations (5, 10, 15, 20, 25 ppm) yielded a regression equation y = 0.1282x – 0.0513 (R^2 = 0.996), demonstrating excellent linearity.

Table 5 shows the methyl cinnamate content of formulations F1 and F2 during accelerated storage at 40 ± 2°C and 75 ± 5% RH for three months. A gradual decrease in methyl cinnamate content was observed in both formulations throughout the storage period. In formulation F1, the content decreased from 88.01% at month one to 84.40% at month two and 47.62% at month three. Similarly, formulation F2 showed a decline from 97.60% to 89.72% and 68.32% over the same period. Despite the observed reduction, methyl cinnamate content in both formulations remained within the acceptable range of 80–120% of the labeled content throughout the three-month storage period.[18] Thus, formulations met requirements through month two but failed compliance at month three.

TPC and YMC assays detected bacterial, mold, and yeast contamination in sunscreen cream, ensuring counts below maximum limits to maintain stability and quality. TPC quantifies mesophilic bacteria per gram/mL; YMC detects molds/yeasts. Colony enumeration on plates with 30–300 colonies (TPC) or 10–150 colonies (YMC). Maximum contamination limit: ≤10^3 CFU/g or mL.[21] TPC and YMC testing revealed microbial contamination in the sunscreen cream formulations, indicating that the products did not comply with the microbiological acceptance criteria of ≤10^3 CFU/g or mL. Although TPC values at the 10^{-1} dilution remained within acceptable limits, counts at the 10^{-2} dilution exceeded the specified threshold. Similarly, YMC results at both dilutions demonstrated mold and yeast contamination above the allowable limits.

The observed contamination may have originated from several sources, including raw materials, processing equipment, manufacturing environment, packaging containers, or handling during formulation and storage. In addition, the absence or insufficient concentration of antimicrobial preservatives may have facilitated microbial growth during storage. Cream formulations, particularly oil-in-water emulsions, contain an aqueous phase that can support the proliferation of microorganisms if adequate preservation is not ensured.[29,30]

To improve microbiological quality, the formulation process should be conducted under stricter hygienic conditions with proper sanitation of equipment and packaging materials. The incorporation of suitable preservatives at effective concentrations, together with microbiological quality control of raw materials and manufacturing processes, is recommended to prevent microbial contamination and enhance product stability during storage.[30,31]

Conclusion

Methyl cinnamate isolate exhibited promising photoprotective activity, with the 0.5% concentration producing an SPF value within the ultra-protection category. Both cream formulations maintained acceptable physical characteristics during 28 days of storage. At day 28, formulation F2 showed a higher SPF value (17.02) than F1 (13.87) and demonstrated better retention of methyl cinnamate content after three months of accelerated storage. However, both formulations failed to meet microbiological quality requirements due to excessive TPC and YMC values. Therefore, further formulation optimization, particularly through the incorporation of an effective preservative system and improved manufacturing hygiene, is required to ensure product stability, safety, and quality. The present study was limited to descriptive evaluation; therefore, no statistical significance testing was performed. Future investigations should incorporate

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appropriate statistical analyses to confirm differences between formulations and storage conditions.

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