

Formulation and Evaluation of Sunscreen Body Lotion Containing Tangerine Oil (*Citrus reticulata*)

Research paper

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Abstract Aim: Using natural ingredients in cosmetics, such as sunscreen, offers a promising approach to creating more environmentally sustainable products. This study aimed to evaluate the feasibility of formulating a sunscreen body lotion containing tangerine oil by assessing its quality, stability, SPF value, and consumer acceptance. Materials and Methods: The study involved phytochemical screening and chemical compound identification using gas chromatography-mass spectrometry (GC-MS). Antioxidant activity was measured using the DPPH method. Additional tests included organoleptic evaluation, homogeneity, pH, viscosity, spreadability, adhesion, emulsion type, particle size, functional group identification, SPF determination, accelerated stability testing (heating-cooling cycles), and hedonic testing. Results: D-limonene was identified as the dominant compound in tangerine oil. It showed weak antioxidant activity, with an IC_{50} value of 72,015.29 ppm and an antioxidant activity index (AAI) of 0.007. All five formulations met the required quality standards. The highest SPF value (13.59) was achieved by the formulation containing 3% TiO_2 and 9% tangerine oil, measured in vitro using a UV-Vis spectrophotometer. Stability testing over six heating-cooling cycles confirmed that all formulations remained stable. In hedonic testing, formula F4 (3% TiO_2 and 12% tangerine oil) was the most preferred by panelists. Conclusions: Although tangerine oil exhibited negligible antioxidant activity, the study successfully developed stable body lotion formulations that met quality requirements, provided maximum sun protection, and were well accepted by users.

Keywords body lotion – evaluation - formula – sunscreen – tangerine oil

INTRODUCTION

Exposure to ultraviolet (UV) radiation can cause various skin problems, including dark spots, sunburn, uneven skin tone, premature aging, and skin cancer. The World Health Organization (WHO) reported over 1.5 million cases of melanoma and nonmelanoma skin cancers worldwide in 2020, with more than 120,000 related deaths (Cives et al., 2020; Ferlay et al., 2020). To reduce these risks, the use of sunscreen is widely recommended. UV radiation levels are also relatively high in many regions, particularly in Asia (Singh et al., 2022).

Sunscreen is classified as a cosmetic product that protects the skin from UV exposure. Titanium dioxide (TiO_2) is a widely used sunscreen agent and is highly effective in shielding the skin from harmful UV radiation. However, TiO_2 does not neutralize free radicals. These radicals are unstable, highly reactive molecules with one or more unpaired electrons. Antioxidants are, therefore, needed to counteract them by donating electrons and inhibiting oxidation reactions.

Natural ingredients are a valuable source of antioxidants, and several studies have highlighted their benefits in cosmetic applications (Dini & Laneri, 2021; Hoang et al., 2021; Liu, 2022; Michalak, 2022).

This study aimed to develop a sunscreen lotion formulation incorporating tangerine (*Citrus reticulata*) oil. Recent studies have shown growing interest in using the tangerine peel for health-related applications, including in food products (Shi et al., 2024). Tangerine peel oil is also recognized in cosmetic industries, which are primarily reported as fragrances and skin conditioning agents (Burnett et al., 2019). In addition, the use of fruit peel which is typically considered as waste would support the green approach toward sustainability. To the best of our knowledge, the incorporation of tangerine oil in sunscreen body lotion has not yet been reported. Therefore, this study evaluates the feasibility of formulating a sunscreen body lotion containing tangerine oil based on the quality and stability tests, SPF value, and consumer preference assessed through hedonic test. The formulated body lotions

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were subjected to multiple evaluations to ensure that they meet the required specifications for sunscreen body lotion products.

MATERIALS AND METHODS

Chemicals

Materials used in this study included tangerine oil (BLISS SCENT brand), distilled water, sulfuric acid (H_2SO_4), iron(III) chloride ($FeCl_3$), acetic anhydride (Ac_2O), Mayer's reagent, Wagner's reagent, hydrochloric acid (HCl), n-hexane, ethanol 96%, 2,2-diphenyl-1-picrylhydrazyl (DPPH), ascorbic acid, titanium dioxide (TiO_2), stearic acid, cetyl alcohol, triethanolamine (TEA), glycerine, liquid paraffin, propylene glycol, phenoxyethanol, citric acid, and methylene blue.

Phytochemical Tests

For the alkaloid test, 2 mL of tangerine oil was placed in a test tube, followed by the addition of 1 mL of 2N HCl. The mixture was heated for 30 minutes until the phase separation occurred. The upper layer was collected and divided into two test tubes. In the first test tube, two drops of Mayer's reagent were added. The formation of a white precipitate indicated the presence of alkaloids. In the second test tube, two drops of Wagner's reagent were added. The formation of a brown precipitate confirmed the presence of alkaloids.

For the flavonoid test, three to seven drops of tangerine oil were placed in a test tube, followed by the addition of a few drops of concentrated H_2SO_4 . A color change to yellow or deep red indicated the presence of flavonoids in tangerine oil. A test tube was filled with three to seven drops of tangerine oil for the terpenoid and steroid tests. Subsequently, two drops of concentrated H_2SO_4 and two drops of Ac_2O were added. A red or orange color indicated the presence of terpenoids, while a blue or purple color indicated the presence of steroids. For the saponin test, a test tube was filled with three to seven drops of tangerine oil, followed by the addition of 5 mL of distilled water (H_2O). The mixture was shaken for 30 seconds. The formation of stable foam indicated the presence of saponins.

For the tannin test, three to seven drops of tangerine oil were added to a test tube. Subsequently, 2 mL of distilled water (H_2O) and 2 drops of 1% $FeCl_3$ solution were added. A greenish-brown color indicated the presence of tannins.

For the phenolic compound test, a test tube was filled with 5 drops of tangerine oil, followed by the addition of 2 drops of 5% $FeCl_3$ solution. The appearance of a black color indicated the presence of phenolic compounds.

Identification of Chemical Compounds

Tangerine oil was subjected to mass spectrometry measurements using a gas chromatography-mass

spectrometry (GCMS-QP2020 Plus, Shimadzu). The column oven temperature was set at 80 °C, while the injection temperature was maintained at 220 °C. The ion source and interface temperatures were fixed at 230 °C and 250 °C, respectively. The oven temperature of 80 °C was held for three minutes before increasing to 275 °C at a rate of 8 °C/min. Once the temperature reached 275 °C, it was held for additional 3 minutes. The mass-to-charge ratio (m/z) was scanned in the range of 30–500 Da.

Antioxidant Activity Tests

The antioxidant assay was carried out using the DPPH method. A total of 320 μ L of DPPH solution (100 ppm) was transferred into a vial and covered with an aluminum foil. Then, 3,680 μ L of 96% ethanol (p.a.) was added to obtain a DPPH solution with a final concentration of 80 ppm. The absorbance was measured over a wavelength range of 200–800 nm, resulting in the determination of the maximum wavelength for DPPH, which was 517 nm.

A solution of ascorbic acid with a concentration of 1000 ppm was prepared by weighing 10 mg of ascorbic acid into a 10-mL volumetric flask and dissolving it in ethanol. Working standard solutions were prepared with varying concentrations of 0, 4, 8, 12, and 16 ppm in 4 mL solutions containing DPPH at a concentration of 80 ppm. The solutions were vigorously shaken and allowed to stand for 30 minutes in the dark. Absorbance was measured using a UV-Vis spectrophotometer (JASCO V-760) at a maximum wavelength of 517 nm.

Samples were prepared by dissolving 1000 mg of tangerine oil in 10 mL of n-hexane using a volumetric flask. Samples with varying concentrations of 0, 2000, 5000, 9000, and 19000 ppm were prepared in 4 mL solutions, each containing 320 μ L of DPPH solution and 3680 μ L of hexanoic tangerine oil solution. The mixtures were homogenized, left to stand in the dark for 30 minutes, and their absorbance values were subsequently measured using a UV-Vis spectrophotometer (JASCO V-760) at a wavelength of 517 nm. The absorbance values were used to calculate the percentage of antioxidant activity. A linear curve was created by plotting the sample concentrations against the percentage of antioxidant activity. The IC_{50} was calculated from the concentration required to achieve 50% inhibition.

Formulation of Sunscreen Body Lotion

The formulation of sunscreen body lotion was carried out as shown in Table 1 and described as follows. The oil phase consisted of stearic acid, cetyl alcohol, phenoxyethanol, and liquid paraffin. The water phase consisted of TEA, glycerin, propylene glycol, citric acid, and distilled water. The oil and water phases were heated separately on a hot plate and stirred using a magnetic stirrer at 75 °C. Once the oil phase had melted, TiO_2 was added and stirred for 15 minutes. When the

Table 1. The formulation of body lotion sunscreen

Ingredients	Concentration (w/v %)				
	FN	F1	F2	F3	F4
Tangerine oil	-	3	6	9	12
TiO ₂	3	3	3	3	3
Stearate acic	5	5	5	5	5
Cetyl alcohol	3	3	3	3	3
TEA	2	2	2	2	2
Glycerin	5	5	5	5	5
Paraffin liquid	8	8	8	8	8
Propylene glycol	8	8	8	8	8
Phenoxyethanol	1	1	1	1	1
Citric acid	1	1	1	1	1
Distilled water (add)	100				

temperature reached 70 °C, the water phase was added to the oil phase with continuous stirring until the lotion mass was formed. The lotion base was allowed to cool to 30–40 °C, after which tangerine oil was added and mixed until homogeneous. Five formulations were obtained as FN (without tangerine oil) and F1–F4 (tangerine oil of 3–12% (w/v)).

Evaluation of Sunscreen Body Lotion

The evaluation of sunscreen body lotion was conducted using an organoleptic test, which included the lotion form, color, texture, and scent. For the homogeneity test, a small amount of lotion was extracted and placed between two glass slides. The sample was observed to examine some coarse particles, clumping, or uneven mixing. The pH of the lotion was measured using a digital pH meter. The viscosity of the lotion was measured using a rotary viscometer. To measure the spreadability, 0.5 g of lotion was weighed and placed in the center of a Petri dish, which was subsequently covered for 1 minute. The diameter of the spread lotion was measured and repeated with weights of 0, 50, 100, 150, and 200 g. The desired spreadability range was 5–7 cm. The adhesion test was performed using 0.25 g sample of the lotion placed between two glass slides. A total weight of 1 kg was applied for 5 minutes. The adhered slides were then attached to a testing device with 80 g weight, and the time required for the two slides to separate was recorded. The values were compared to the specifications listed in the Indonesia National Standards (SNI 16-4399-1996).

To determine the emulsion type, a small amount of lotion was placed on a glass slide, and methylene blue was added. The mixture was homogenized and observed under a microscope. An oil-in-water emulsion would demonstrate a blue outer phase. The particle size distribution was tested by capturing images of the lotion globules using an Optilab microscope. Measurements were performed by drawing two lines across each globule using image raster software, and the average globule size along with standard deviation was calculated. Functional groups in the tangerine oil were identified

using an ATR-FTIR spectroscopy (JASCO FTIR-6800) within a wavenumber range of 400–4000 cm⁻¹. The transmittance value to determine the SPF value was measured using ultraviolet-visible spectrometry (UV-Vis, Jasco V-760).

The accelerated stability test was conducted by placing the lotion in an oven at 40 °C with normal humidity for 24 hours, followed by refrigeration at 4 °C for another 24 hours. This process was repeated six times to complete six heating-cooling cycles. After completing the cycles, the organoleptic properties and pH changes were observed.

Hedonic Test

The hedonic test involved untrained 82 panelists. The parameters evaluated by the panelists included color, aroma, texture, absorbency, and overall preference for the sunscreen body lotion. The evaluation was based on a numerical scale from 1 to 5, with the following ratings: 1 (strongly dislike), 2 (dislike), 3 (neutral), 4 (like), and 5 (strongly like).

RESULTS AND DISCUSSION

Phytochemical Screening

The phytochemical tests were carried out on the tangerine oil. The alkaloid test used two reagents, which were Mayer's and Wagner's reagents. The addition of Mayer's and Wagner's reagents yielded positive results, as confirmed by the formation of a white precipitate with Mayer's reagent and a brown precipitate with Wagner's reagent (Maheshwaran et al., 2024; Shaikh & Patil, 2020). The formation of precipitates upon reagent addition indicates the presence of alkaloid complexes with metal ions such as potassium ions (K⁺). Before adding the reagents, HCl was added to enhance solubility, as alkaloids would react with HCl to form salts that are more soluble in water.

The reddish-orange color obtained from the reaction between tangerine oil and concentrated sulfuric acid indicates the presence of flavonoid compounds (Maheshwaran et al., 2024; Shaikh & Patil, 2020). This suggests the formation of flavylum salts, which cause a deep red or orange color. The terpenoid-steroid compound test resulted in an orange color without subsequent changes. The addition of concentrated sulfuric acid is intended to break the glycosidic bonds in the compounds, freeing the steroid-terpenoid groups, as indicated by the color change to orange. This result aligns with the primary component of tangerine oil, limonene, which is classified as a terpenoid. The absence of a color change to purple or blue in the steroid compound test indicated a negative result.

The saponin test showed a negative result, as no stable foam was produced after shaking (Maheshwaran et al., 2024; Shaikh & Patil, 2020). On the other hand, the tannin test produced a greenish-brown color, indicating a positive result for the presence of tannins. The phenolic compound test showed

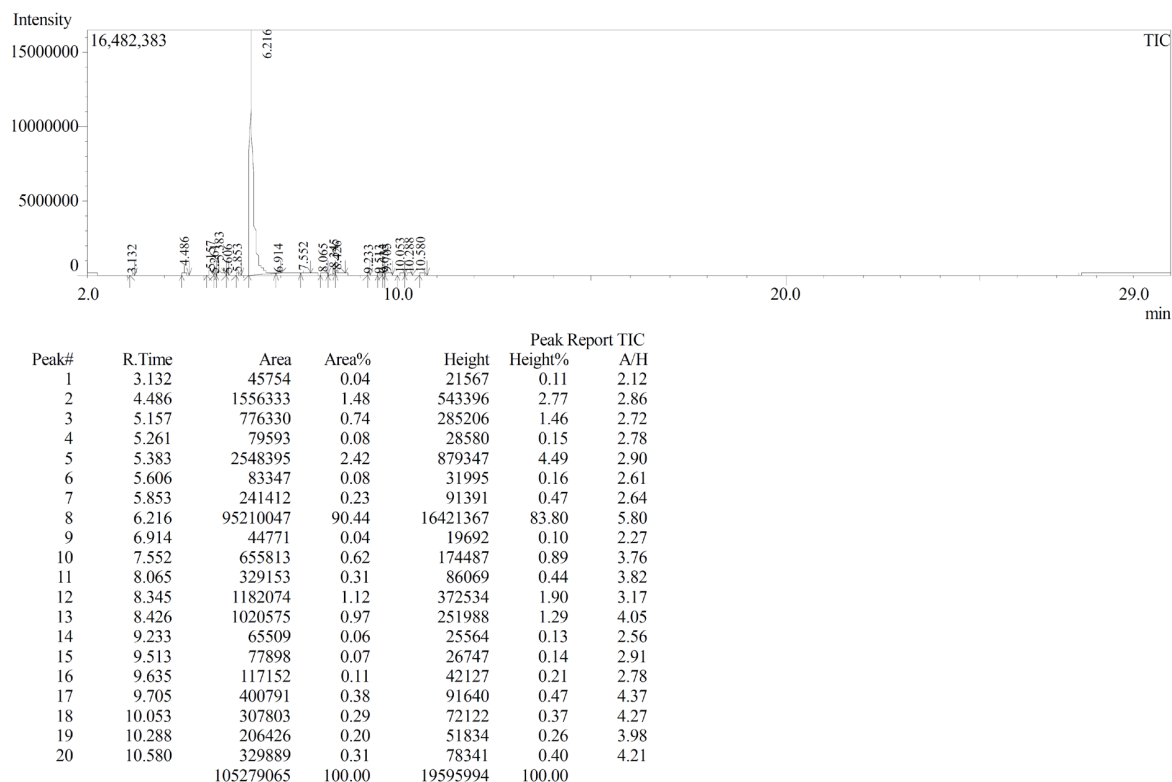


Figure 1. Chromatogram of tangerine oil and the information of retention time, area, and height of the detected peaks

a color change to dark brown, confirming the presence of phenolic compounds in tangerine oil. These results are consistent with other studies (Costanzo et al., 2022; Ishfaq et al., 2021), which also reported the presence of flavonoid and phenolic compounds in tangerine oil. Therefore, in line with the previous finding (Justin et al., 2014), the chemical constituents of *Citrus reticulata* peel include alkaloids, flavonoids, terpenoids, phenolic compounds, and tannins.

Chemical Composition

The chromatogram and selected mass spectrometry (MS) spectra of the tangerine oil are presented in Figs. 1 and 2. As illustrated in Fig. 1, the tangerine oil contains one dominant compound with a retention time of 6.216 min, accounting for 90.44% of the area and a height of 83.80%. According to the MS spectrum shown in Fig. 2 (a), this dominant compound was identified as D-limonene. Additionally, two other major compounds were detected, with retention times of 4.486 and 5.383 min. These were determined to be α -pinene and β -myrcene, respectively, as depicted in Fig. 2 (b) and 2 (c).

Antioxidant Activity

The IC_{50} value is typically used to categorize the strength of inhibition or antioxidant activity in a quantitative assay as

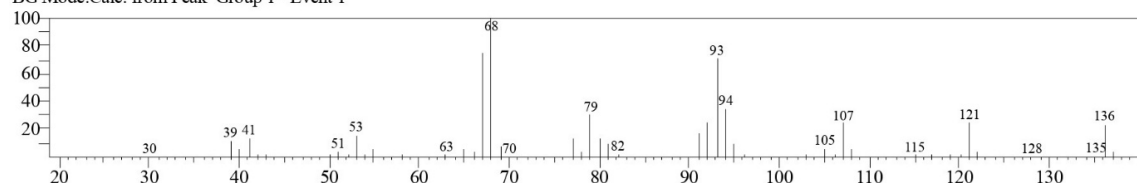
follows: < 50 ppm is considered very strong, 51–100 ppm is considered strong, 101–150 ppm is moderate, 151–200 ppm is weak, and > 200 ppm is very weak (Setha et al., 2013). Another parameter to evaluate the antioxidant activity is the antioxidant activity index (AAI). The value of AAI describes the strength of antioxidant activity and is calculated by dividing the concentration of DPPH by the IC_{50} value of the sample (Mahboub & Memmou, 2014; Scherer & Godoy, 2009). The AAI ranges are typically used to classify the strength of the antioxidant. There are four levels of antioxidants with AAI: < 0.5 (weak), > 0.5 (moderate), 1–2 (strong), and > 2 (very strong).

For comparison purposes, the antioxidant activity of ascorbic acid was measured in ethanol at 517 nm. The linear plot of inhibition percentage versus concentration is shown in Fig. 3 (a). The IC_{50} value of ascorbic acid was determined to be 7.97 ppm, which falls into the category of a very strong antioxidant. While there is no standardized IC_{50} value, the obtained IC_{50} value is still in the range of the reported values (Nariya et al., 2013; Saha et al., 2008). On the other hand, the DPPH concentration was 56.96 ppm, yielding an AAI value of 7.15 for ascorbic acid, which classifies it as a very strong antioxidant.

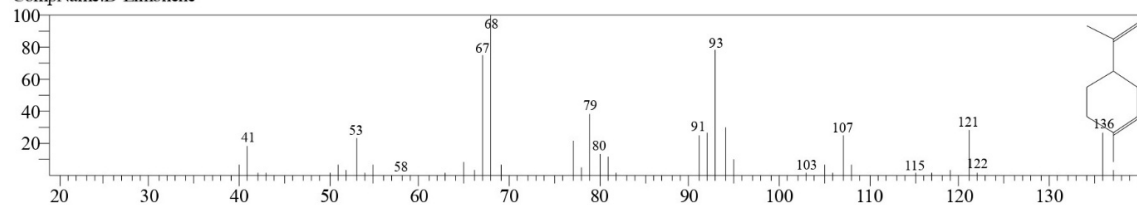
As clarified by the GC-MS, the main composition of the tangerine oil was D-limonene, which is nonpolar, making it more soluble in nonpolar solvents. In this case, the tangerine

Line#:8 R.Time:6.217(Scan#:507) MassPeaks:78
RawMode:Averaged 6.208-6.225(506-508) BasePeak:68.05(2712939)
BG Mode:Calc. from Peak Group 1 - Event 1

(a)

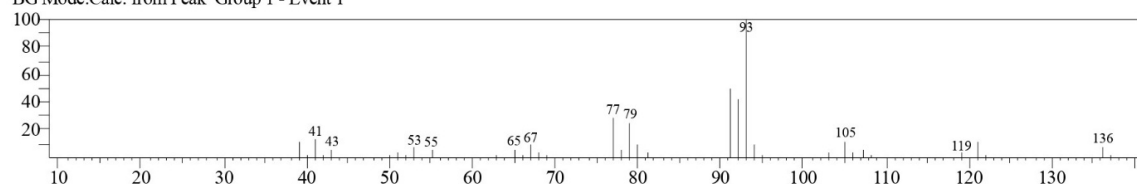


Hit#:1 Entry:18356 Library:NIST17.lib
SI:95 Formula:C₁₀H₁₆ CAS:5989-27-5 MolWeight:136 RetIndex:1018
CompName:D-Limonene

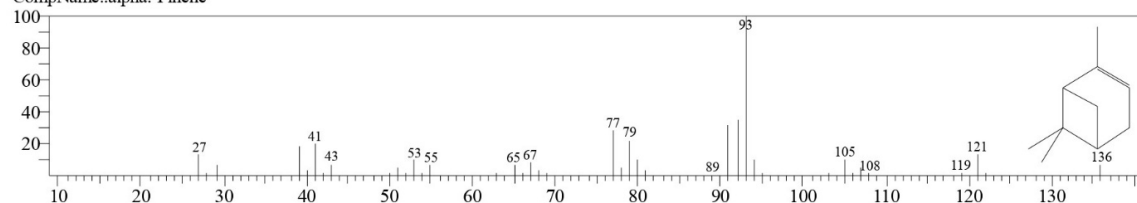


Line#:2 R.Time:4.483(Scan#:299) MassPeaks:40
RawMode:Averaged 4.475-4.492(298-300) BasePeak:93.05(128481)
BG Mode:Calc. from Peak Group 1 - Event 1

(b)

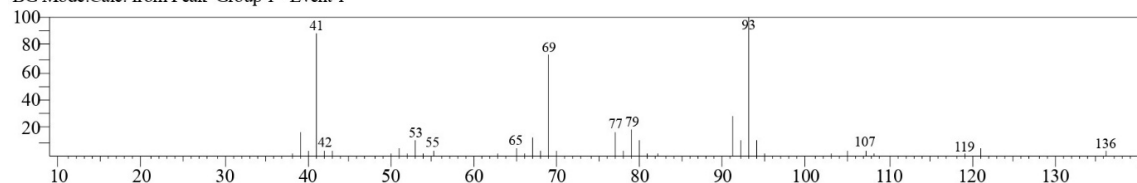


Hit#:1 Entry:18417 Library:NIST17.lib
SI:96 Formula:C₁₀H₁₆ CAS:80-56-8 MolWeight:136 RetIndex:948
CompName:alpha-Pinene



Line#:5 R.Time:5.383(Scan#:407) MassPeaks:39
RawMode:Averaged 5.375-5.392(406-408) BasePeak:93.05(173515)
BG Mode:Calc. from Peak Group 1 - Event 1

(c)



Hit#:1 Entry:18386 Library:NIST17.lib
SI:96 Formula:C₁₀H₁₆ CAS:123-35-3 MolWeight:136 RetIndex:958
CompName:beta-Myrcene

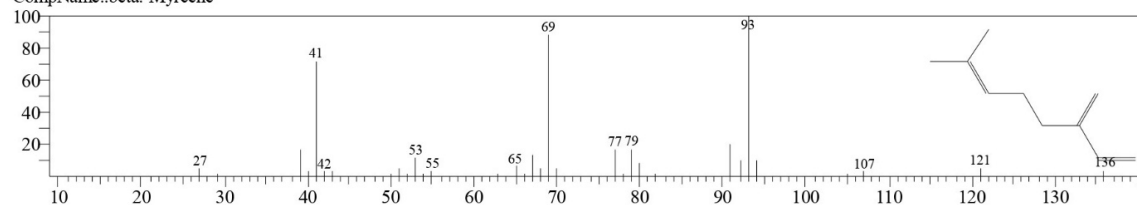


Figure 2. MS spectra of selected main chemical compounds in tangerine oil, which are (a) D-limonene, (c) alpha-pinene and beta-myrcene

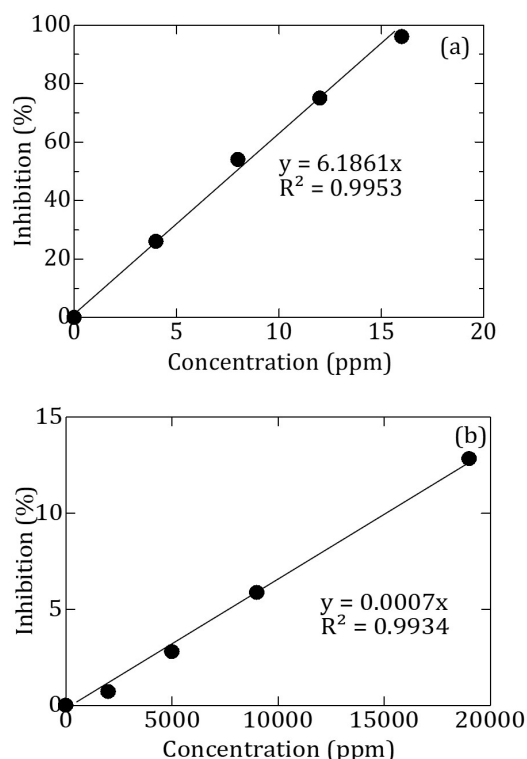


Fig. 3. Linear plots of DPPH inhibition percentage versus concentration of (a) ascorbic acid and (b) tangerine oil

oil was dissolved in n-hexane. As shown in Fig. 3 (b), the plot of inhibition percentage versus tangerine oil concentration was linear. As the concentration of tangerine oil increases, the percentage of inhibition also rises. A higher percentage of inhibition indicates that more free radicals are neutralized by tangerine oil. This also suggests that the greater the amount of tangerine oil added to a sunscreen formulation, the better its ability to neutralize free radicals.

The IC_{50} value of tangerine oil was then calculated to be 72,015.29 ppm, while the DPPH concentration was 56.19 ppm. This IC_{50} value classifies tangerine oil as a very weak antioxidant. The calculated AAI value was 0.0007, which also places it in the category of a weak antioxidant. This AAI value is close to that reported by Lin et al. (2021), with an AAI of 0.001. It is, however, better compared to the results reported by Denkova-Kostova et al. (2020), which showed an AAI value of 0.00006.

Evaluation of Sunscreen Body Lotion

All formulations of the sunscreen body lotion featured a soft and semi-solid texture. The formulations from F1 to F4 had a citrus scent derived from tangerine oil, while the FN formulation was unscented due to the absence of tangerine oil. All formulations were white, which was the base color of the emulsion. Additionally, the inclusion of TiO_2 contributed to the lotion base's white color. However, formulations F2, F3,

and F4 exhibited a slightly yellowish-white. All formulations exhibited good homogeneity, with all ingredients well-dispersed, and no clumps observed in the preparations.

As listed in Table 2, the pH testing results for the five formulations ranged from 7.6 to 7.7, thereby complying with the specifications requiring a pH range of 4.5–8.0, which is suitable for skin pH (22). Results of ANOVA testing showed a P -value of more than 0.05, indicating no significant difference in the pH of the formulations. Therefore, the addition of tangerine oil to the formulations did not affect the pH, ensuring that the quality of the formulations was maintained. The viscosity test results for the five formulations met the expected specifications, with a viscosity range of 500–5000 cP (Table 2). These results indicated that higher concentrations of tangerine oil in the formulation resulted in lower viscosity of the preparation. Tangerine oil is a liquid with low viscosity, and therefore, its addition to the formula affects the overall viscosity of the preparation.

The adhesion test results for the five sunscreen body lotion formulations ranged from 1.7 to 2.65 s, as shown in Table 2. This range meets the adhesion specification of > 1 s. The longer a formulation adheres to the skin surface, the more active ingredients can be absorbed, thereby increasing the effectiveness of the topical formulation. ANOVA test results showed a P -value of less than 0.05, indicating a significant difference in the adhesion of the formulations. The least significant difference (LSD) test showed that FN was not significantly different from F1 and F2 ($p > 0.05$), while the other groups differed significantly. These results indicate that adhesion increased significantly only at tangerine oil concentrations of 9% and 12% (F3 and F4). Although there was a difference in adhesion between the FN formulation and the F3 and F4 formulations, the addition of tangerine oil at concentrations of 9% and 12% did not affect the quality of the sunscreen preparations, as all formulations still met the specifications.

Body lotion should have spreadability range with a diameter of 5–7 cm. Active ingredients will have a larger contact surface with the skin if the lotion can be applied more easily. Additionally, good spreadability ensures that TiO_2 can be evenly distributed across the skin surface. The spreadability test results for the five tangerine oil sunscreen body lotion formulations met the specifications, ranging from 5.69 to 6.36 cm, as shown in Table 2. ANOVA test results showed a P -value of less than 0.05, indicating a significant difference in the spreadability of the formulations. Similar to the adhesion test result, the LSD test confirmed that the spreadability of the FN was not significantly different from that of F1 and F2 but significantly different from F3 and F4. These results again indicate that spreadability of the lotion increased significantly only at tangerine oil concentrations of 9% and 12% (F3 and F4). However, the difference in spreadability between the FN formulation and the F3 and F4 formulations did not affect the quality of the sunscreen preparations, as the spreadability range obtained for all five formulations remained within the expected specifications.

Table 2. The evaluation of body lotion sunscreen

Formulation	pH fresh	Viscosity (cP)	Adhesion (s)	Spreadability (cm)	Particle size (mm)	pH after stability test	SPF value
FN	7.67 ± 0.03	1500	2.65 ± 0.17	5.69 ± 0.15	2.03 ± 0.10	7.69 ± 0.11	12.82 ± 0.07
F1	7.66 ± 0.22	1300	2.58 ± 0.08	5.84 ± 0.72	2.11 ± 0.26	7.80 ± 0.05	12.30 ± 0.05
F2	7.76 ± 0.12	850	2.51 ± 0.05	6.06 ± 0.59	1.72 ± 0.02	7.91 ± 0.05	13.19 ± 0.14
F3	7.72 ± 0.10	600	2.15 ± 0.09	6.24 ± 0.45	2.30 ± 1.15	7.89 ± 0.06	13.59 ± 0.06
F4	7.70 ± 0.35	500	1.70 ± 0.18	6.36 ± 0.18	2.22 ± 1.16	7.93 ± 0.02	13.24 ± 0.08

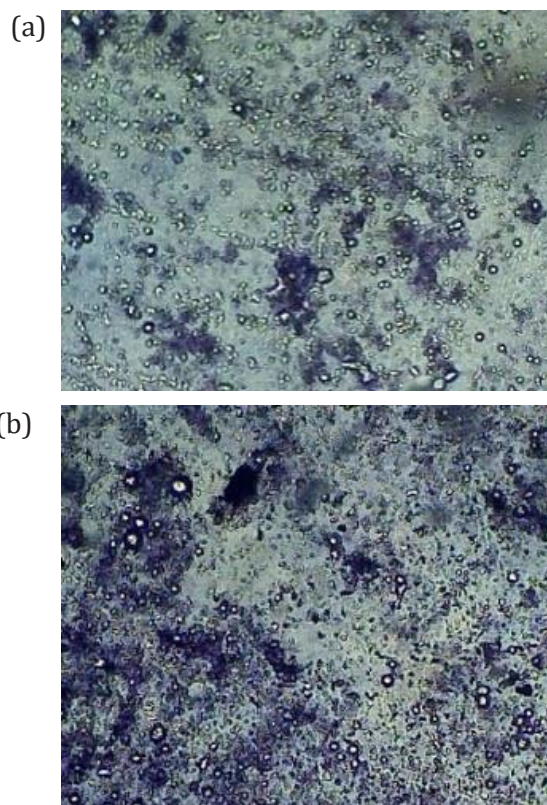


Figure 4. Micrographs of selected (a) F3 and (b) F4 formulas

The emulsion type test results for the five formulations indicated that the sunscreen had an oil-in-water (O/W) emulsion type. This was evident from the colorless globules, representing the oil phase, while the outer part of the globules, representing the water phase, appeared blue as shown in Fig. 4. Methylene blue dissolved in water, and thus, the blue phase corresponded to the water phase, and the colorless phase corresponded to the oil phase.

As shown in Table 2, the globule size for the five formulations ranged from 1.72 to 2.30 μm . The antilog of the standard deviation (SD) for each formulation was used to assess globule size uniformity. If the antilog SD value is > 1.2 , the emulsion globules are considered polydisperse, whereas if the antilog SD is < 1.2 , the globules are considered monodisperse. All formulations exhibited monodisperse globules with antilog

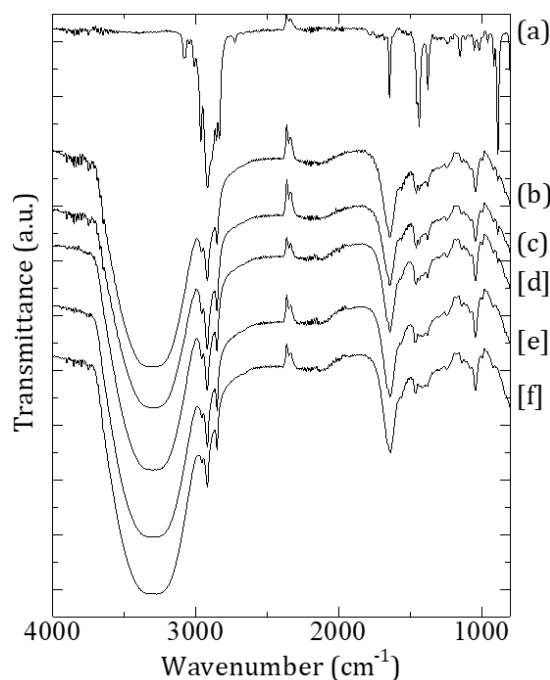


Figure 5. FTIR spectra of (a) tangerine oil, (b) F4, (c) F3, (d) F2, (e) F1, and (f) FN samples.

SD values < 1.2 . ANOVA test results showed a P -value of less than 0.05, indicating a significant difference in the globule size of the formulations. The LSD test showed that the particle size of FN was insignificantly different with F1 and F4 but significantly different from F2 and F3. There was no clear trend on the effect of tangerine oil concentration on the particle size. The difference in globule size between the FN formulation and the F2 and F3 formulations did not affect the quality of the preparations, as they still met the expected specifications.

The FTIR spectrum analysis of the sunscreen samples from formula FN and formula F4 revealed differences. As shown in Fig. 5, tangerine oil showed an absorption band at 2917 cm^{-1} , corresponding to the CH_2 functional group (Flores et al., 2024; Manaila et al., 2016). The bands between 2850 and 2920 cm^{-1} detected the presence of C-H stretching. The absorption in the range of 1575–1825 cm^{-1} indicated C=C-H bonds. An absorption band at 1435–1436 cm^{-1} detected symmetric and asymmetric C-H groups. Additionally, the bands between

950 and 1225 cm^{-1} showed the presence of $-\text{CH}_2-$ groups and C-H groups in the aromatic ring, while the absorption band at 885–886 cm^{-1} detected C=C bending in the aromatic ring. All the sunscreen samples exhibited the characteristics of tangerine oil absorption bands, except for the FN sample. The FN formula lacked the C=C bending functional group at 885–886 cm^{-1} and the C-H group at 1435–1436 cm^{-1} . On the other hand, F1, F2, F3, and F4 formulas showed the FTIR spectra indicative of the presence of tangerine oil in the formulations. The higher the concentration of tangerine oil in the formulations, the sharper the characteristics absorption bands observed.

The SPF value was determined by measuring the transmittance values at wavelengths between 290 and 400 nm. As shown in Table 2, the SPF value of the body lotion without the addition of tangerine oil, referred to as FN, was 12.82. This result indicates that the observed SPF value was primarily due to the presence of TiO_2 . In contrast, the body lotions containing tangerine oil exhibited SPF values ranging from 12.3 to 13.59. The results of the ANOVA test revealed a significant difference ($p < 0.05$), prompting the use of the LSD test as a post hoc analysis. It was found that all groups differed significantly from one another, except for those containing 3% and 12% tangerine oil (F2 and F4). When 3% tangerine oil was added to the body lotion, the SPF value dropped to 12.3. However, as the concentration of tangerine oil increased to 6% and 9%, the SPF values rose to 13.19 and 13.59, respectively. Unfortunately, further increasing the concentration of tangerine oil to 12% resulted in a decrease in SPF value to 13.24. The effectiveness of sunscreen protection is categorized as follows. The SPF value of 2–4 is considered minimal protection, 4–6 shows medium protection, 6–8 is extra protection, 8–15 is maximum protection, and ≥ 15 indicates ultra-protection (Shabrina et al., 2025). Based on these ranges, all five formulas are categorized as maximum protection. Even though the addition of tangerine oil did not significantly increase the SPF value, the highest SPF was achieved in formulation F3, which contained 9% tangerine oil.

Feasibility of Sunscreen Body Lotion Containing Tangerine Oil

In this study, we evaluated the feasibility of a body lotion containing tangerine oil through various physical and chemical tests, including stability testing, SPF value assessment, and consumer acceptance testing. As previously discussed, the formulated body lotion met the specifications for pH, viscosity, adhesion, and spreadability, and it also provided maximum protection according to its SPF values. To assess the stability of the formulation, we conducted accelerated stability testing using heating–cooling cycles.

The organoleptic tests before and after heating–cooling cycles showed no changes in color, aroma, or appearance of the formulations. Homogeneity tests revealed no clumping or separation of oil and water phases in any of the formulations.

Additionally, the homogeneity tests confirmed that all five formulations remained homogeneous after the heating–cooling test. The pH values indicated a slight change in pH, but it remained within the specified range of 4.5–8. The pH values after six cycles were between 7.6 and 7.9. The ANOVA test results showed a P -value of less than 0.05, indicating a significant difference in the pH of the formulations after the stability test. It can be concluded that the addition of tangerine oil to the formulations affects the pH after six cycles of the stability test. The difference in pH between the FN formulation and the F2, F3, and F4 formulations was acceptable, as it still met the specifications and did not affect the quality of the formulations.

Applying a sunscreen body lotion that is suitable for the skin's pH is crucial for maintaining the skin's acid mantle, which is essential for the proper functioning of the skin barrier. While many studies reported that the normal skin pH ranges from 4.1 to 5.8, recent researches have indicated that the upper surface of the stratum corneum has a near-neutral pH (Proksch, 2018; Fukuda et al., 2024, Brooks et al., 2025). Fukuda et al. (2024) have identified three distinct junctions with varying pH levels in the stratum corneum. The upper layer has a near-neutral pH of 6.7, the middle layer is more acidic at 5.4, and the lower part exhibits a moderately acidic pH of 6. Only the upper layer can adapt to the pH of the external environment. Therefore, the use of cosmetics, such as sunscreen body lotion, can raise the pH of the skin in the upper layer. In light of this, the pH of sunscreens should be formulated to be less than 8, allowing the skin to maintain a lower pH than that of blood, which typically ranges from 7.35 to 7.45 (Brooks et al., 2025).

Another safety concern in formulating sunscreen body lotion is toxicity under light exposure. The photosensitizing and phototoxicity of tangerine oil have been investigated. In a human maximization study involving 25 patients, tangerine oil (8% in petrolatum) was found to be nonsensitizing (Burnett et al., 2019; Ford et al., 1992). After 48-hour closed patch tests, the same formulation showed no irritation in five patients (Burnett et al., 2019; Ford et al., 1992). The phototoxicity of undiluted tangerine oil was also evaluated in mice and swine, with no phototoxic response observed (Burnett et al., 2019; Forbes et al., 1997). In contrast, lemon oil, lime oil, and bitter orange oil demonstrated phototoxic effects (Burnett et al., 2019; Forbes et al., 1997; Naganuma et al., 1985). Overall, these findings suggest that tangerine oil has low toxic potential under light exposure.

Consumer preference was investigated through hedonic test. As shown in Fig. 6 (a), the most preferred color was that of formula F4, which exhibited a yellowish-white hue, while the most favored aroma was from formula F1. The citrus scent in formula F1 was milder compared to the stronger aromas of formulas F2, F3, and F4. The texture of formula F4 was also the most preferred, encompassing the softness of the product when applied to the skin and its viscosity. Additionally, formula F4 was the most favored by panelists in terms of absorbency. The Kruskal–Wallis test yielded a P -value of less

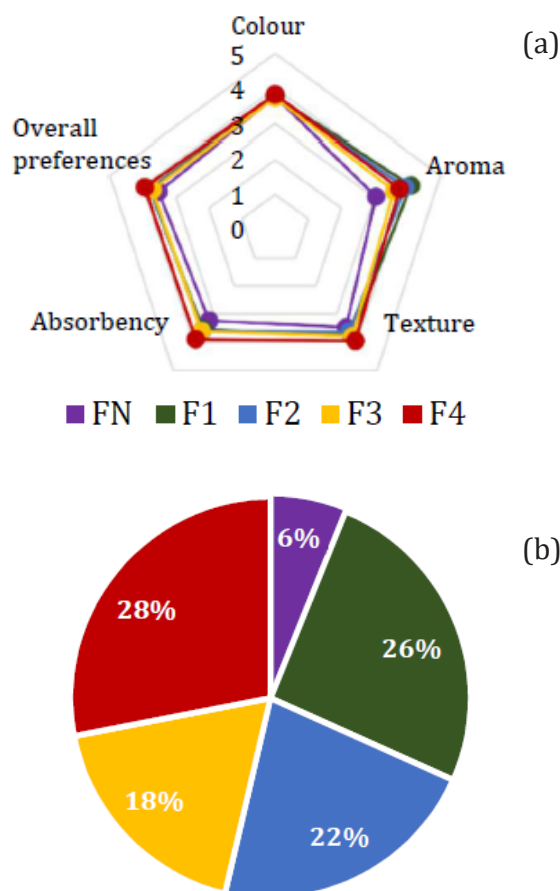


Figure 6. (a) Spider diagram of hedonic evaluation and (b) percentage pie chart for overall preference

than 0.05, indicating a difference in the overall preference ratings for each formulation by the panelists. Based on the average overall preference in Fig. 4 (b), it was shown that the addition of tangerine oil to the formulation increased the overall preference rating among the panelists with the F4 formula being the most preferred by the panelists.

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CONCLUSION

Sunscreen body lotion containing tangerine oil met the required specifications for pH, viscosity, adhesion, spreadability, and stability. The lotion was an oil-in-water emulsion, exhibiting good homogeneity and a monodispersed particle distribution with a particle size ranging from 1.72 to 2.30 μm . The formulation also provided maximum protection against UV exposure. Based on panelist feedback, the tangerine oil contained lotion achieved higher acceptance than the formulation without it, particularly in appearance, color, scent, texture, and skin absorbency. Overall, incorporating tangerine oil into body lotion sunscreen is feasible and offers a promising approach to using natural ingredients in cosmetic applications.

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