


## Formulation and Determination of SPF Value of Sunscreen Spray with *Cymbopogon Nardus* L. Essential Oil

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Article Info	ABSTRACT
<p><b>Keywords:</b> Cymbopogon nardus Essential Oil Sunscreen spray Sun Protection Factor</p>	<p>Ultraviolet light exposure creates free radicals in skin causing skin problems. To overcome this, sunscreens containing synthetic chemical substances can absorb ultraviolet rays and ward off free radicals that are formed, but the downside of sunscreen creams and lotions is that they are sticky and need to be adjusted to human skin type. Essential oil from <i>Cymbopogon nardus</i> L. containing citronellal, geraniol, and other flavonoid compounds which have sunscreen and antioxidant activity can be developed into a sunscreen preparation, namely spray sunscreen which is non-sticky and suitable for all skin types. The objective of this study was to obtain a sunscreen spray formula containing citronella essential oil that meets all physical preparation test requirements and has the highest SPF value. The research design is laboratory experimental study with citronella essential oil formulated in four variations of sunscreen spray formula (F0, F1, F2, F3) with concentrations of 0%, 5%, 7.5%, and 10%. The research methods are essential oil extraction by steam-water distillation, phytochemical screening, formulation, physical evaluation (organoleptic, pH, homogeneity, and viscosity testing), and SPF activity test using spectrophotometer UV-Vis. All formulas exhibited acceptable physical characteristics with a constant pH of 7, homogeneous, and varying viscosity. The highest SPF values was F3 (12.13±0.00) with low protection. These results indicate that citronella essential oil can be incorporated into a sunscreen spray formulation that meets physical quality requirements and provides UV protection with the highest SPF value owned by F3.</p>
<p>This is an open-access article under the <a href="https://creativecommons.org/licenses/by-nc/4.0/">CC BY-NC</a> license</p> 	<p><b>Corresponding Author:</b> Ellsya Angeline Rawar Faculty of Pharmacy, Universitas Kristen Immanuel Jalan Solo Km 11, 1, Yogyakarta <a href="mailto:ellsya@ukrimuniversity.ac.id">ellsya@ukrimuniversity.ac.id</a></p>

### INTRODUCTION

Exposure to ultraviolet (UV) radiation remains one of the major environmental risk factors that contribute to skin damage, photoaging, hyperpigmentation, suppression of the immune system, and the development of skin cancer. The increasing intensity of UVB radiation due to environmental and climatic changes demands the development of effective photoprotective strategies (Nafiah et al., 2024). Conventional sunscreens predominantly use synthetic UV filters such as oxybenzone, octinoxate, or avobenzone can absorb ultraviolet rays and ward off free radicals that are formed. However, these compounds have been widely reported to trigger skin irritation, oxidative stress, and environmental toxicity, leading to growing public

concern. Thus, the exploration of plant-derived bioactive compounds with antioxidant and UV-absorbing capabilities has become a promising approach for safer and more sustainable sunscreen innovation (Mukarram et al., 2022).

Citronella grass (*Cymbopogon nardus* L.) is an aromatic plant known for its abundant essential oil content and diverse biological activities (Parman, 2023). Its essential oil contains flavonoids, triterpenoids, tannins, saponins, citronellal, citronellol, and geraniol compounds that have been scientifically recognized for their antioxidant, antimicrobial, anti-inflammatory, and antiproliferative properties (Pontes et al, 2018; Balfas & Rahmawati, 2022). These bioactive constituents, especially flavonoids and phenolic compounds, possess the ability to absorb UV radiation and neutralize free radicals, making citronella essential oil a potential natural photoprotective agent (Afrizal et al., 2024). Citronella grass has relatively high essential oil yield, which is around 0.5–1.5% of the fresh leaf weight (A'yun et al., 2020). Therefore, it has potential to be developed in sunscreen preparation.

Research on sunscreen formulations has primarily concentrated on extracts from other plants or different essential oils (Mukarram et al., 2022). Previous studies have investigated that citronella oil has been formulated in the form of sunscreen lotion with the oil concentration of 5% which has low sunscreen activity with an SPF value between 15.20–20.00 (Antari et al, 2024). The choice of sunscreen dosage form, such as creams, gels and lotions should have consider to the human's skin type, namely normal, dry or oily skin. Sunscreen in lotion form tends to have a thicker texture so it takes longer to absorb into the skin, and causes a sticky or uncomfortable feeling after use (Nurlaila et al., 2024). Lotions are more appropriate for normal to oily skin due to their low viscosity, which makes them easier to spread. Cream or gel dosage forms may cause discomfort, greasy feel, occlusion, and reduced user compliance especially for frequent reapplication. Creams, on the other hand, are more suitable for dry skin, and gels are ideal for oily skin because they are oil-free (Rachmawati et al., 2021). To overcome this problem, sunscreen preparation that can be used by all skin types, for example sunscreen spray, is needed. The advantages of sunscreen spray are light and non-sticky texture, more homogeneous particle dispersion, improved stability due to reduced oxidation within closed spray packaging, and is suitable for all skin types (Kartikasari et al., 2023). The unique contribution of this study lies in formulating citronella essential oil into a spray sunscreen preparations.

In addition to the gap in dosage form innovation, the scientific problem addressed in this study concerns the lack of natural sunscreen agents that simultaneously provide UV protection and antioxidant activity while maintaining acceptable physical quality parameters (Nurhaliza et al., 2025). Essential oils are known to be volatile, prone to oxidation, and may affect viscosity, pH, and homogeneity of topical formulations (Prihandini et al., 2023). Therefore, the formulation of citronella essential oil into a spray system requires careful optimization to maintain stability, prevent phase separation, and ensure maximal UV absorbing performance. Determining how different concentrations of citronella essential oil influence SPF values and formulation characteristics is necessary to establish the most effective and stable composition (Kurniawan et al., 2020).

Considering these gaps and practical needs, this research was conducted to formulate a sunscreen spray containing citronella grass essential oil and to evaluate its physical properties, including organoleptic characteristics, pH, viscosity, and homogeneity (Nurhaliza et al., 2025). Furthermore, the study determines the sunscreen potential through in-vitro Sun Protection Factor (SPF) measurement using UV-Vis spectrophotometry. This work is expected to contribute scientific evidence regarding the feasibility of citronella essential oil as a natural photoprotective agent and the potential of spray formulations as an innovative, user-friendly alternative to conventional sunscreens (Zubaydah et al., 2022). The results are also anticipated to serve as a reference for the future development of natural-based skin protection products that are safe, effective, and environmentally friendly (Desbrianto et al., 2024). The objective of this study was to obtain a sunscreen spray formula containing citronella essential oil that meets all physical preparation test requirements and has the highest SPF value.

## METHOD

This study used a laboratory experimental research design with the independent variable being the concentration of citronella essential oil varying from 0% (F0), 5% (F1), 7.5% (F2), to 10% (F3) in the sunscreen spray formula. The sunscreen spray formula used was a modification of the sunscreen spray formula with the active ingredient of cherry leaf extract studied by Shabrina and Nurwaini (2023). The additional ingredients used were carbopol as a gel base, propylene glycol as a humectant, propyl paraben as a preservative, triethanolamine as an emulsifier, methyl paraben as a preservative, oleum rosae as a fragrance, and aquadest as a solvent. The percentages of the formulas used were adjusted to the standards of Rowe et al. (2023) because the concentration of the some additives used in Shabrina and Nurwaini (2023) was outside the standard concentration range in Rowe et al. (2023). Therefore, the concentration of carbopol at 0.1% from a standard range of 0.1-0.5%, propylene glycol at 15% from a standard of 15%, propylparaben at 0.01% from a standard range of 0.01-0.6%, triethanolamine at 2% from a standard range of 2-4%, methylparaben at 0.02% from a standard range of 0.02-0.3%, and oleum rosae at 0.01% from a standard range of 0.01-0.5%. The four formulas were replicated three times, resulting in three physical and SPF tests for each formula. After the sunscreen spray formula was produced, physical tests (organoleptic, pH, homogeneity, viscosity) and SPF potential determination was conducted. All tests were replicated three times. All numerical data is calculated using a standard deviation value to demonstrate the validity of the observation results. If the standard deviation value is less than the average value, the data is accurate. The obtained viscosity value and SPF values were analyzed statistically using the Shapiro-Wilk normal distribution test and the Levene homogeneity test. If the data were normally distributed and homogenous, the One-Way ANOVA test was continued. If the data were not normally distributed and homogeneous, the Kruskal-Wallis test was continued. If there were significant differences, the Mann Whitney is used to determine which formula has a significant difference.

## Tools and Materials

The tools used were steam-water distillation, Stahl distillation (Pyrex®), analytical balance (Ohaus Pioner®), basin, gram scale (SF-400), measuring cup (Pyrex®), measuring flask (Iwaki®), stirring rod, porcelain cup, volume pipette, Bunsen burner, test tube (Pyrex®), test tube rack, beaker glass (Pyrex®), hot plate, object glass, Brookfield viscometer (NDJ-8S), UV-Vis spectrophotometer (B-One), and cuvette. The materials used in the manufacture of essential oils were citronella grass leaves obtained from Imogiri, Bantul, Yogyakarta. The materials used in the formulation and testing are carbopol, propylene glycol, triethanolamine, methyl paraben, propyl paraben, oleum rosae, distilled water, magnesium powder, concentrated HCl, FeCl<sub>3</sub>, hydrochloric acid, sulfuric acid, reagents (Wagner, Mayer, and Dragendroff), and pH paper.

## Citronella Grass Essential Oil Extraction (*Cymbopogon nardus* L.)

The obtained citronella grass leaves are cut or shredded into 2-5 cm pieces, then air-dried without direct sunlight. This cutting process aims to increase the surface area of the material, thus optimizing the release of essential oils. The prepared leaves are placed in a steam-water distillation apparatus. The steam penetrates the leaf tissue and carries away the volatile essential oil components. The mixture of steam and oil is then flowed to a condenser to be cooled until it turns back into a liquid mixture of water and oil. This mixture then enters an oil separator, where the citronella essential oil is separated from the water due to the difference in density of the oils in the upper layer. The distillation process typically takes 3-6 hours, with a yield of around 0.5-1.5% of the fresh leaf weight (Goddess & Hanifa, 2021). The distillation results of the essential oil are then separated using a Stahl distillation apparatus to separate the water from the oil that is still mixed, then stored in a tightly closed container and protected from light, then covered with aluminum foil and stored at room temperature (Febrianti & Ariani, 2020).

## Phytochemical Screening

Phytochemical screening was carried out based on the method carried out by Balfas (2022):

- a. Identification of flavonoid compounds  
A 1 mL sample is taken, a few drops of concentrated HCl are added and a little Mg powder is added. It is declared positive if the color changes to red, yellow, orange or orange.
- b. Identification of Tannin Compounds  
Add 1 mL of FeCl<sub>3</sub> solution and hydrochloric acid to 1 mL of the sample. If it contains tannin, it will show the formation of a dark blue, blue-black, or greenish-black color.
- c. Identification of Saponin compounds  
Take 3-7 drops of the sample and add 5 mL of distilled water to a test tube. Shake vigorously for 30 seconds, resulting in a stable foam that lasts for approximately 10 minutes, reaching a height of 1-10 cm.
- d. Identification of Alkaloid Compounds  
A sample of 2 mL was taken plus 1 mL of sulfuric acid heated for 30 minutes, then left to stand and allow the solution to separate, the sulfuric acid layer was taken and then

divided into 3 tubes. Tube 1 was added with 2 drops of Wagner reagent, positive if a brown precipitate formed. Tube 2 was added with 2 drops of Mayer reagent, positive if a white precipitate formed. Tube 3 was added with Dragendorff reagent, positive if an orange precipitate formed.

### Sunscreen Spray Formulation for Citronella Grass Essential Oil (*Cymbopogon nardus* L.)

The formula was taken from Shabrina & Nurwaini (2023) which has been modified to fit the standard concentration range according to Rowe et al., (2023). The preparation formulation process begins by adding carbopol into some of the previously heated aquadest while stirring until homogeneous. The mixture is left for approximately 30 minutes for the carbopol to expand completely. Add triethanolamine (TEA) slowly while continuing to stir until a clear and stable gel base is formed. Next, propyleneglycol is added to the gel base, followed by the addition of methylparaben and propylparaben which have previously been dissolved in a small amount of propyleneglycol.

The next step is to add the active ingredient, citronella grass essential oil, according to the formula concentration (5%, 7.5%, or 10%), little by little while stirring until the mixture is homogeneous. Oleum rosae is added, then distilled water is added until the total volume reaches 100 mL, while stirring slowly to ensure the preparation remains homogeneous and prevents phase separation (Antari et al., 2024).

**Table 1.** Citronella grass essential oil sunscreen spray formula

No	Material	Formula 0	Formula 1	Formula 2	Formula 3
1	Citronella grass oil	0%	5%	7.5%	10%
2	Carbopol	0.1%	0.1%	0.1%	0.1%
3	Propylene glycol	15%	15%	15%	15%
4	Propyl paraben	0.01%	0.01%	0.01%	0.01%
5	TEA	2%	2%	2%	2%
6	Methyl paraben	0.02%	0.02%	0.02%	0.02%
7	<i>Oleum rosae</i>	0.01%	0.01%	0.01%	0.01%
8	Aquadest	ad 100 mL	ad 100 mL	ad 100 mL	ad 100 mL

### Physical Quality Determination

a. Organoleptic test

Organoleptic testing is a test conducted through direct or visual observation of a product. Organoleptic testing is conducted by observing the product's texture, color, and aroma (Handayani & Rosidah, 2017).

b. pH test

Dip the tip of the pH paper into the preparation. Compare the color change that occurs on the pH paper with the indicator and record the results (Warnida et al., 2023)

c. Homogeneity test

The homogeneity test is performed by spraying a spray bottle onto a glass slide and then covering it with another glass slide. Visual inspection is performed to check for phase separation or coarse particles. If no lumps or particles are present, the preparation is considered homogeneous (Kresnawati et al., 2022).

d. Viscosity test

The formulation was placed in a 100 mL beaker, and the appropriate spindle was selected for each formula. The instrument was then set to 30 rpm and the spindle was immersed in the formulation until the instrument displayed a viscosity value. A good viscosity range is between 50-5000 cPs (Anindhita and Oktaviani, 2020).

e. Determining the SPF value

The SPF value was tested in vitro using UV-Vis spectrophotometry. Two grams of each formula was weighed and transferred to a 25 mL volumetric flask. 96% ethanol was added to the mark. The diluted solution was measured for absorbance at a wavelength of 290-320 nm with a 5 nm interval. Absorbance measurements were performed three times. The SPF value was calculated using the following equation:

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

Note :

- SPF = Sun Protection Factor
- CF = Correction Factor
- EE = Spectrum of erythema effects
- I = Light intensity spectrum
- Abs = Absorbance

## RESULTS AND DISCUSSION

### Yield of Citronella Grass Essential Oil

The plants of citronella grass used were obtained from Imogiri, Bantul, Yogyakarta. To ensure the authenticity of the plants used, determination of citronella grass (*Cymbopogon nardus* L.) was carried out at the Laboratorium Struktur dan Pertumbuhan Tumbuhan (SPT) of the Faculty of Biology, Gadjah Mada University with No. 01029/S.Tb./XI/2025.

**Table 2.** Results of Yield Calculation of Citronella Grass Essential Oil

Initial plant weight (grams)	Weight of oil produced (grams)	Yield (%)
2519	18.2805	0.72%

The distillation process of citronella grass leaves with an initial weight of 2519 grams of material produced 18.2805 grams of essential oil with a yield of 0.72%. The yield of citronella grass essential oil obtained in this study was in the range of 0.5-1.5%, so it can be said that the extraction results were in accordance with the characteristics of citronella grass as a plant with a relatively high essential oil content (Kurniawan et al., 2020).

### Phytochemical Screening of Citronella Essential Oil

**Table 3.** Phytochemical Screening Results of Citronella Grass Essential Oil

Identification	Reference	Results	Conclusion
Flavonoid	Red, yellow, orange or orange	Orange	Positive
Tannin	Dark blue, blackish blue or greenish black	Yellow	Negative
Saponin	White sediment or foam	White sediment or foam	Positive

Identification	Reference	Results	Conclusion
Alkaloid	Brown sediment (tube 1)	Black	Negative
	White sediment (tube 2)	Orange with black sediment	(tube 1) Negative
	Orange sediment (tube 3)	Black	(tube 2) Negative (tube 3)

Based on the results of phytochemical screening, the sample was declared to contain flavonoid compounds as indicated by a color change into orange in accordance with a positive reaction in research conducted by Balfas & Rahmawati (2022). It was also stated that the flavonoid results were declared positive as indicated by the formation of an orange color in the amyl alcohol layer. The samples also showed a positive reaction to saponins through the formation of white deposits or foam. In research conducted by Balfas & Rahmawati (2022), it was also stated that the saponin test results were positive with the formation of foam. In the tannin compound test, negative results were shown because the dark blue to greenish black color did not appear. In the research conducted by Syaputri et al (2023), it was also showed negative results in the tannin test, possibly because the extraction process carried out was unable to extract the tannin compounds from the material or because the concentration of tannin was very low in the part of the plant used. Likewise, alkaloids gave negative results in the three test tubes because no sediment was formed and no color change was consistent with research conducted by Balfas & Rahmawati (2022) which also stated that the alkaloids were declared negative, possibly because the alkaloid content in citronella grass essential oil was very low or non-existent, so that no color changes or sediment occurred. It can be concluded that citronella essential grass oil contains flavonoids and saponins.

#### Organoleptic Characteristics of Sunscreen Spray Formulations

**Table 4.** Organoleptic Test Results

Parameter	Formula 0	Formula 1	Formula 2	Formula 3
Texture	Thick	Thick	Thick	Thick
Color	Clear	Milky white	Milky white	Light yellow
Aroma	Oleum rosae	Citronella grass	Citronella grass	Citronella grass

Note : replication has been carried out three times



**Picture 1.** The organoleptic test results with three replication, namely first replication (a), second replication (b), and third replication (c)

The organoleptic test results showed that all formulas had thick textures. Differences in color and aroma were due to the addition of citronella grass essential oil. The control formula

(F0) had clear color with an oleum rosae aroma, while the color of F1 and F2 were milky white and F3 was light yellow with a distinctive citronella grass odor. This indicates that the addition of essential oils affected the characteristics of color and aroma, but did not affect the formula's texture.

### pH Evaluation of Formulations

**Table 5.** pH Test Results





Formula	Results
F0	7±0
F1	7±0
F2	7±0
F3	7±0

Note : replication has been carried out three times

All formulas have a pH value of 7, indicating neutrality. The resulting pH value falls within the pH range required by SNI 16-4399-1996, which is 4.5–8.0, making it safe for use on the skin. Therefore, all formulas meet pH requirements and do not have the potential to cause irritation due to excessively acidic or alkaline pH (Tungadi et al., 2023).

### Homogeneity Evaluation

**Table 6.** Results of Homogeneity Test

Formula	Results
F0	 Homogeneous
F1	 Homogeneous
F2	 Homogeneous
F3	 Homogeneous

Note : replication has been carried out three times

The homogeneity test results showed that all formulas had a uniform appearance without any visible phase separation or particles (Salwa et al., 2020). It is stated that the constituent ingredients are well mixed in the gel base, so that the preparation can be distributed homogeneously.

### Viscosity Evaluation

**Table 7.** The Results of Viscosity Test

Viscosity value (centipoise/cPs)				
Formula	I	II	III	Mean±SD
F0	720	710	721	717±6.08
F1	1072	1060	1060	1064±6.92
F2	508	484	472	488±18.33
F3	580	580	576	578.66±2.30

Note : replication has been carried out three times

The result of viscosity tests showed that each formula had a different viscosity value. F1 with a 5% essential oil concentration had the highest viscosity of 1064±6.92 cPs, in contrast to F2 with a 7.5% essential oil concentration and F3 with a 10% essential oil concentration, which did not differ much in viscosity values, namely 488±18.33 cPs and 578.66±2.30 cPs, respectively. The higher the concentration of essential oil, the higher the volatile compound content. Volatile compounds have a lower molecular weight so that they can reduce viscosity by disrupting intermolecular interactions (Miroshnichenko, 2024). In addition, active compounds in citronella oil such as citronellal and geraniol can act as surfactants. Citronellal acts as a viscosity-modifying agent, usually contributing to a decrease in viscosity when incorporated into an aqueous surfactant system (Ameliana et al, 2019). Based on research conducted by Ameliana et al (2019), the higher the concentration of citronella essential oil, the lower the viscosity of the shampoo. Geraniol is an amphiphilic molecule, meaning it has both a hydrophilic (water-loving) and a lipophilic (oil-loving) portion so that it acts as a co-surfactant and typically reduces the viscosity of surfactant solutions by altering the micelle structure (Kamada et al, 2014). Geraniol positions itself within the surfactant's interfacial layer (the boundary between the oil and water phases) so that it can transform large, viscous, worm-like micelles into smaller, less tangled, spherical micelles, resulting in a significant reduction in overall viscosity (Kamada et al, 2014).

**Table 8.** The Mann Whitney Result of Viscosity Result

Formula	F0	F1	F2	F3
F0	-	0.046	0.050*	0.050*
F1	0.046	-	0.046	0.046
F2	0.050*	0.046	-	0.046
F3	0.050*	0.043	0.046	-

Note : \*significantly different

The results of the normality test show that F0 and F2 have normal data, namely p-values of 0.157 and 0.637 (p-value > 0.05), while F1 and F3 do not have normal data, namely both have p-values of 0.00 (p-value <0.05). The results of the homogeneity test significance

show 0.062 ( $p$ -value > 0.05), so the data is homogeneous. Because the data were not normally distributed, the Kruskal Wallis test was continued. The Kruskal Wallis test showed a  $p$ -value of 0.015, indicating a significant difference. Therefore, a post-hoc test was conducted using Mann-Whitney. The post-hoc Mann-Whitney test showed no significant difference in viscosity between F2 and F3.

#### SPF Value Determination

**Table 9.** The Results of Determination of SPF Value

Formula	SPF value			
	I	II	III	Mean±SD
F0	3.24	3.23	3.23	3.23±0.01
F1	9.45	9.22	9.39	9.35±0.12
F2	11.44	11.36	11.41	11.40±0.04
F3	12.13	12.13	12.13	12.13±0.00

Note : replication has been carried out three times

**Table 8.** The Mann Whitney Result of SPV value Result

Formula	F0	F1	F2	F3
F0	-	0.046	0.050*	0.046
F1	0.046	-	0.046	0.043
F2	0.050*	0.046	-	0.046
F3	0.046	0.043	0.046	-

Note : \*significantly different

The results of the normality test show that F2 and F3 have normal data, namely  $p$ -values of 0.485 and 0.726 ( $p$ -value > 0.05), while F0 and F1 do not have normal data, namely both have  $p$ -values < 0.05. The results of the homogeneity test significance show 0.011 ( $p$ -value < 0.05), so the data is not homogeneous. Because the data were not normally distributed and not homogeneous, the Kruskal Wallis test was continued. The Kruskal Wallis test showed a  $p$ -value of 0.014, indicating a significant difference. Therefore, a post-hoc test was conducted using Mann-Whitney. The post-hoc Mann-Whitney test showed no significant difference in SPF value between F2 and F3.

Based on the test results using the UV-Vis spectrophotometry method, the SPF value obtained shows that increasing the concentration of active ingredients in the formulation has an effect on increasing the protective ability against UV radiation (Kartikasari et al., 2023). F0 has an SPF value of 3.23 which is included in the very low protection category, so it does not provide optimal protection for the skin, because in F0, only as a negative control, had no active ingredients are added. Oleum rosae is added in F0 in order to make the preparation slightly scented. According to Abdallah et al., (2023), oleum rosae contains phenolic and flavonoid compounds that act as antioxidants and thus have the potential to absorb UV radiation. Therefore, it can be said that oleum rosae contributes to provide SPF potential, although the value is small. F1 has an SPF value of 9.35±0.01, while F2 and F3 each show SPFs of 11.40±0.04 and 12.13±0.00. All three formulas are in the low protection category according to BPOM RI, which means they can provide basic protection against UVB exposure. The

increase in SPF value from F1 to F3 also shows a relationship between increasing concentration of active ingredients and the ability to absorb UV radiation, so that citronella grass essential oil has potential as a natural sunscreen agent (Prihandini et al., 2023). The modest increase in SPF between formulas indicates that the effectiveness of UV absorption is not only influenced by the concentration of the active ingredient, but is also likely influenced by the stability of the active ingredient in the preparation. Other factors such as the volatility of citronella essential oil as an active ingredient can also cause some components to evaporate quickly, resulting in less than optimal UV protection. Interactions between formulation components and the efficiency of active ingredient distribution also have the potential to affect the SPF value. Therefore, it is concluded that citronella essential oil has potential as a natural sunscreen agent, but further optimization of both concentration and formulation is needed to achieve higher protection.

## CONCLUSION

Variations in the concentration of citronella grass essential oil in the sunscreen spray formula (5%, 7.5%, and 10%) do not affect the texture, aroma, and pH, namely a thick texture, citronella grass aroma, and a constant pH value of 7, but affect the color, viscosity, and potential protection against ultraviolet rays. The higher the concentration of citronella grass essential oil, the color changes from milky white (F1 and F2) to light yellow (F3). The viscosity of F1, F2, and F3 varies, from  $1064 \pm 6.92$  cPs (F1) to  $578.66 \pm 2.30$  cPs (F3). The potential SPF increases from  $9.35 \pm 0.12$  (F1) with very low protection to  $12.13 \pm 0.00$  (F3) with low protection. In conclusion, F3 meets the physical quality parameters and has the highest SPF value. The limitation of this research is that formula optimization has not been carried out. Besides that, particularly the absence of in vivo SPF testing, stability evaluation, and skin irritation assessment, which limits comprehensive interpretation of the formulation's long-term performance and safety profile. Therefore, future studies are recommended to include stability testing under various storage conditions, in vivo SPF measurements, more extensive concentration optimization, and irritation or sensitization testing to ensure safety for continued use on the skin. Further exploration of formulation strategies to increase SPF values such as microencapsulation, combination with other natural UV filters, or modification of the spray system is also recommended to maximize the photoprotective potential of citronella essential oil.

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