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Optimization and Evaluation of Patchouli (Pogostemon cablin Benth.) Leaf Essential Oil Gel using Carbopol and Triethanolamine

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ABSTRACT

The essential oil of Patchouli (*Pogostemon cablin* Benth.) has antioxidant activity and can be used as an active compound in sunscreen preparations. The index used to describe the effectiveness of sunscreen products is the Sun Protection Factor (SPF). Patchouli oil has never been developed as a sunscreen in gel dosage form. The exploration of patchouli oil is more about testing antioxidant and antibacterial activity. This research aims to optimize the formula and test the SPF (Sun Protection Factor) value of essential oil of Pogostemon cablin gel preparations. Formula optimization using Simplex Lattice Design 13 contained in Design Expert software. The variables optimized in this study were carbopol and triethanolamine concentrations. The responses used in the optimization process are pH, viscosity, adhesion and spreadability. The optimum formula was evaluated by evaluating the preparation, including organoleptic, homogeneity, pH, viscosity, adhesive power, spreadability, stability and SPF value test using the UV-Vis spectrophotometric method. The results showed that the optimum formula composition was obtained from a combination of 0.5% carbopol and 0.7% triethanolamine. The optimum formula gel preparation has a yellow appearance and smell typical of patchouli oil, homogeneous, the pH of the preparation is 6.29 ± 0.08, the viscosity of the preparation is 44086.67 ± 1510.69, the adhesive power is 7.62 ± 0.68, the spreadability of 5.42 ± 0.08, stable. The optimum formula gel preparation has an ultra-protection SPF value of 28.87 ± 0.27.

***Keywords*:** Optimization; Carbopol; Triethanolamine; Simplex lattice design; *Pogostemon cablin*

INTRODUCTION

One of the free radicals from Reactive Oxygen Species (ROS) is formed by exposure to ultraviolet light. Excessive free radicals will change pathological skin, even chronic diseases such as photoaging, immunosuppression, and photo-carcinogenesis.[1,2] The compound antioxidant can neutralize radical-free with the method of donating electrons, for radical-free so that electrons free become paired and stop damage in the body.[3]

Patchouli (*Pogostemon cablin* Benth.) is a shrub plant with the content Of patchouli alcohol, which has characteristic antioxidants with the method of donating one hydrogen atom (H) to a radical to form a more stable.[4,5] Based on research conducted by Rachmatillah et al. (2021) shows that the IC_{50} value for oil-essential leaf

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patchouli is 34.12 ppm, including in intensity potent.[6]

Compounds with potent antioxidant activity can be used as compounds in sunscreen preparations. Sunscreen is a cosmetic product that can physically and chemically inhibit the penetration of UV rays into the skin.[7–9] The index commonly used to describe the effectiveness of sunscreen products is the Sun Protection Factor (SPF). The Sun Protection Factor (SPF) number shows the capacity of a sunscreen product to protect the skin.[10]

The gel is a semisolid system consisting of a suspension made from small inorganic particles or large organic molecules penetrated by a liquid.[11] The gel preparation consists of a gelling agent as a thickening agent, which works by forming a structural network. Carbopol is a hydrophilic gelling agent that is easily dispersed by water. A small concentration of 0.5 – 2% carbopol has sufficient viscosity as a gel base.[12] Carbopol tends to have an acidic pH and will not form a stable gel in an acidic pH environment, so a base, namely triethanolamine, is needed as a pH stabilizer and forms a gel mass.[13] Combining these two ingredients is expected to create a stable gel preparation.

Carbopol and triethanolamine were optimized using the simplex lattice design method. The simplex lattice design method is a technique or method for optimizing formulas with different ingredient compositions. The advantage of this method is that it minimizes the number of ingredients used because it can find the optimal formula with fewer trials.[14]

The aims of the research were carried out on formula optimization and testing the SPF (sun protection factor) value of patchouli leaf essential oil gel preparations (*Pogostemon cablin* Benth.) using the gelling agent carbopol and the alkalizing agent triethanolamine. The two material components, namely Carbopol and Triethanolamine, were optimized using the simplex lattice design method in Design Expert 13.0.5.0 software to obtain a gel formula with optimum physical properties.

METHODS

This research used an experimental design; the first stage was to optimize the gel preparation formula for patchouli leaf essential oil with variations in carbopol and triethanolamine components, and then an optimum SPF gel preparation test was carried out.

The instrument used in this research were glassware (Pyrex, Indonesia), Petri dishes, stirring rods, spatulas, mortars and stampers, dropper pipettes, analytical balance (Ohaus, USA), gel pots, glass slides, hot plates (Thermo Scientific, USA), viscometer (Brookfield Ametek, USA), spreadability test glass, adhesion test instrument, stopwatch, UV-Vis spectrophotometer (Thermo Scientific, USA) and pH meter (Martini MI 150, US).

The material used in the research is patchouli leaf essential oil (*Pogostemon cablin* Benth.) produced by Tetesan Atsiri Bogor, which has a CoA (Certificat of Analysis). The additional exipient with Cosmetic Grade is Carbopol (Lubrizol, Indonesia). Additional pharmaceutical-grade exipient are triethanolamine (Alpha Chemika, India), Glycerin (Avantor Performance Material, USA), Propyl Paraben and Methyl Paraben (Yokkaichi Factory, Japan), Ethanol p.a (Brataco, Indonesia) and Aquadest.

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Optimization of Patchouli Leaf Essential Oil Gel Formula

Optimization was carried out using Design Expert software. The software enters the lower and upper limit values to obtain eight-run formulas. The formula was made according to the software's variations, and physical properties were tested, including organoleptic tests, homogeneity, pH, viscosity, adhesion, and spreadability. The pH, viscosity, stickiness, and spreadability test results were included as response parameters to determine the optimum formula for patchouli leaf essential oil gel preparations. The formula for patchouli leaf essential oil gel preparation can be seen in Table 1.

Table 1. The formula for Patchouli Leaf Essential Oil Gel Preparation

Materials	Concentration (%)
Patchouli Leaf Essential Oil	5
Carbopol 940	0.5 – 1.1
Triethanolamine	0.1 – 0.7
Glycerin	20
Propyl Paraben	0.02
Methyl Paraben	0.18
Aquadest ad	100

The preparation of the gel begins with carbopol 940 sprinkled over distilled water in a mortar until it swells. Then methyl and propyl paraben are dissolved in glycerin and stirred until homogeneous to form a mixture (B). Next, mixture (B) is added to mixture (A) and crushed until homogeneous. The essential oil of crushed patchouli leaves was then added until homogeneous. Triethanolamine was added little by little. Finally, the remaining distilled water was added while grinding until a gel formed.[15]

Physical Properties Test of Gel Preparations

Organoleptic

0.5 grams of gel was taken and applied to a glass object. Visual observations include color, odor, and gel form changes.[16]

Homogeneity

The gel preparation was applied to transparent glass. According to SNI No.06-2588 requirements, the absence of coarse grains or lumps in the preparation indicates the homogeneity of the patchouli leaf essential oil gel preparation is suitable.[17]

pH

The pH meter detector was dipped into the gel preparation. The pH value on the pH meter monitor was observed[8]. According to SNI No.06-2588 requirements, the pH value of the gel should align with the normal pH of the skin, which is 4.5-6.5.[17]

Viscosity

The Brookfield viscometer container was filled with patchouli leaf essential oil gel until the spindle was completely submerged. Viscosity measurements are carried out using spindle 64. The ideal viscosity of the gel ranges from 6000 to 50,000 cP.[18]

Adhesion Test

0.25 grams of gel was taken and placed on the specified glass object. Another glass object was placed on top of the gel smear. A load of 1 Kg was added to the glass object for 5 minutes. Then, a weight of 80 grams was released until the glass objects were separated. The time of release from the glass object was recorded. Good adhesion time is more than four seconds.[17]

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Spreadability Test

0.5-gram gel preparation is placed in a petri dish, overlaid with another petri dish on top of the gel mass, and left for 1 minute. The diameter of the spread gel is measured (the average length and diameter of several sides are taken). The same procedure is then carried out with additional loads of 50 grams, 100 grams, and 150 grams. Based on the requirements of SNI No. 06-2588, good gel spreadability is 5-7 cm.[17]

Patchouli Leaf Essential Oil Gel Preparation

The optimal formula was obtained by considering the adhesive power, spreadability, pH, and viscosity response and inputting the desired target or range of values. A formula with a maximum desirability value close to 1.0 is optimal, demonstrating the program's ability to fulfill desires based on set criteria or targets and produce increasingly perfect products.[19]

Verification of Optimum Formula for Patchouli Leaf Essential Oil Gel Preparation

The optimum formula results obtained from the Design Expert 13.0.5.0 software were created, and the physical properties were tested. The test results were compared with the predicted response from the software using the One Sample T-test.

Gel Stability Test

The gel stability test of patchouli leaf essential oil was carried out using centrifugation. The optimal formula gel preparation was inserted into the centrifuge. Then, a centrifugation test was conducted at 5000 rpm for 30 minutes. The handling of the test sample is equivalent to experiencing gravity for one year. Observations were then made to see whether there was any separation in the preparation.[20]

SPF Gel Test

The SPF value of sunscreen gel was determined using a UV spectrophotometer instrument. The optimal gel preparation, weighing 1 gram, was placed in a measuring flask and dissolved in 10 mL of ethanol. The absorbance value of the diluted samples was measured using a UV-Vis spectrophotometer at wavelengths of 290–320 nm (UV-B) at 5 nm intervals, with ethanol pa used as a blank solution. The SPF value was noted and calculated using the Mansur equation.[21]

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

where :
EE : Erythermal effect spectrum
I : Solar intensity spectrum
Abs : Absorbance of sunscreen product
Cf : Correction factor (=10)

RESULTS AND DISCUSSION

The variations in the concentration of the gelling agent carbopol and the alkalizing agent triethanolamine produced from the Design Expert 13.0.5.0 software consisted of 8 runs. The combination of carbopol and triethanolamine was chosen because carbopol is a gel-forming agent whose gel-forming effectiveness greatly influences the pH of the preparation. When carbopol is dissolved in water, the structure has not been ionized, so adding triethanolamine will shift the ionic balance, making the mixture form a water-soluble salt structure. As a result, ionic repulsion occurs on the carboxylate groups in carbopol to form a gel structure.

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Patchouli leaf essential oil gel was prepared using eight formulas obtained from the simplex lattice design. The result of the characteristic evaluation of Patchouli Leaf Essential Oil Gel Preparations is shown in Table 2, and the equation of the effect of the concentration of carbopol and triethanolamine on the response of the preparation according to the Simplex Lattice Design is shown in Table 3.

Table 2. Characteristic evaluation of Patchouli Leaf Essential Oil Gel Preparations

Run	Organoleptic	Homogeneity	pH	Viscosity (cP)	Adhesion Time	Spreadability (cm)
1	Thick, yellow, typical of patchouli oil scent	Homogeneous	5.51	58080	12.55	5.325
2	Slightly thick, yellow, typical of patchouli oil scent	Homogeneous	6.44	42120	7.4	5.47
3	Exceptionally thick, yellow, typical of patchouli oil scent	Homogeneous	5.14	59460	16.36	5.275
4	Exceptionally thick, yellow, typical of patchouli oil scent	Homogeneous	4.65	63000	19.55	5.075
5	Exceptionally thick, yellow, typical of patchouli oil scent	Homogeneous	4.54	59940	17.41	5.175
6	Thick, yellow, typical of patchouli oil scent	Homogeneous	5.44	58200	13.27	5.3
7	Slightly thick, yellow, typical of patchouli oil scent	Homogeneous	6.20	42360	8.41	5.575
8	Slightly thick, yellow, typical of patchouli oil scent	Homogeneous	6.02	48660	9.69	5.425

Information :
Carbopol concentration: Triethanolamine (R1 = 0.8%:0.4% ; R2 = 0.5%:0.7% ; R3 = 0.95%:0.25% ; R4 = 1.1%:0, 1% ; R5 = 1.1%:0.1% ; R6 = 0.8%:0.4% ; R7 = 0.5%:0.7% ; R8 = 0.65%:0.55%)

Table 3. Equation of the effect of the concentration of carbopol and triethanolamine on the response of the preparation according to the Simplex Lattice Design

Response	Equation
pH	pH = 4.63(A) + 6.36 (B)
Viscosity	Viscosity = 61404.90(A) + 41911.57 (B) + 21204.71
Adhesion time	Adhesion time = 18.52(A) + 7.64 (B)
Spreadability	Spreadability = 5.13(A) + 5.52 (B)

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The eight patchouli leaf essential oil gel runs followed a suitable pH standard range for the skin, between 4.5 and 6.5.[17] Based on the test results (Table 2), the pH of run 7 and run 7 is the highest because these formulas have the lowest concentrations of carbopol and the highest triethanolamine. Runs 4 and 5 have the lowest pH because these formulas have the highest carbopol concentration and the lowest triethanolamine concentration. Where carbopol has properties that tend to be more acidic, namely having a pH of 2.5 – 3, which results in the higher the concentration of carbopol, the more acidic the resulting gel preparation is. In the equation from the pH response, it can be seen that the most dominant factor influencing the pH value is triethanolamine (6.36) compared to carbopol (4.63). Carbopol tends to have an acidic pH, namely 2.5 – 3 and triethanolamine has a pH above 8. The stability of carbopol will be disturbed in an acidic pH environment, so triethanolamine is necessary as a pH stabilizer to maintain the stability of gel preparations.[18]

Based on the results of viscosity testing on eight runs, it was found that three runs met the standard range for suitable gel viscosity, namely runs 2, 7, and 8. Run 4, with the highest carbopol concentration, had the highest viscosity value, namely 63,000 cP. Meanwhile, run 2, with the lowest carbopol concentration, obtained the lowest viscosity value, 42120 cP. This is because carbopol is a gel-forming agent, where the higher the concentration of carbopol, the viscosity value of the gel preparation will increase.[18] The equation from the viscosity response shows that the factor that has the most influence on the viscosity value is carbopol (61404.90) compared to triethanolamine (41911.57). In addition, the combination of carbopol and triethanolamine can affect the viscosity of the gel. The effect is proven by the equation showing that the carbopol and triethanolamine mixture positively responds to viscosity with a coefficient value of 21204.71, where triethanolamine will increase the gel's viscosity when mixed with carbopol.[21]

The gel's adhesion time on eight runs reaches the criteria for good adhesion of gel preparations, namely more than four seconds.[21] Run two, the formula with the lowest concentration of carbopol, had the fastest adhesion. Run four, the formula with the highest concentration of carbopol has the longest adhesion. The high concentration of carbopol can increase the adhesion of the gel preparation.[15] Based on the equation of adhesion time, it can be seen that the factor that has the most influence on the adhesive strength value is the proportion of carbopol (18.52) compared to triethanolamine (7.64). Adding carbopol concentration will increase the sticking time of patchouli leaf essential oil gel.[22]

The results of the adhesion test on eight gel runs showed that the adhesion power of the gel on eight runs met the criteria for good adhesion of gel preparations, namely more than 4 seconds 62. Run 2, the formula with the lowest concentration of carbopol, had the fastest adhesion (7.4 seconds). Run 4, the formula with the highest concentration of carbopol has the longest adhesion (19.55 seconds). The high concentration of carbopol can increase the adhesion of the gel preparation.[15] Based on the equation from the spreadability response, it can be seen that the proportion of

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triethanolamine (5.52) has the most influence on the spreadability value of the gel preparation compared to carbopol (5.13). This follows research conducted by Rahayu et al. (2016), which found that triethanolamine provides a more dominant response influencing the spreadability value of gel preparations than carbopol.[23]

From each response, the criteria of the optimal formula were determined, such as maximize, minimize, in range, target or equal. From the target, DoE predicted the composition of carbopol and triethanolamine and the response value (pH, viscosity, adhesion time, and spreadability). The optimum formula point shows that the optimum formula for patchouli leaf essential oil gel preparations that can provide physical properties of the preparation close to ideal is run two and run 7 (figure 1) with desirability value 1. This formula combines 0.5% carbopol and 0.7% triethanolamine with a predicted pH value of 6.35694, viscosity 41911.6 cP, adhesion power 7.63889 seconds, and spreadability 5.52083 cm. The graph of Variation of Two Components on Desiribilty is shown in Figure 1.

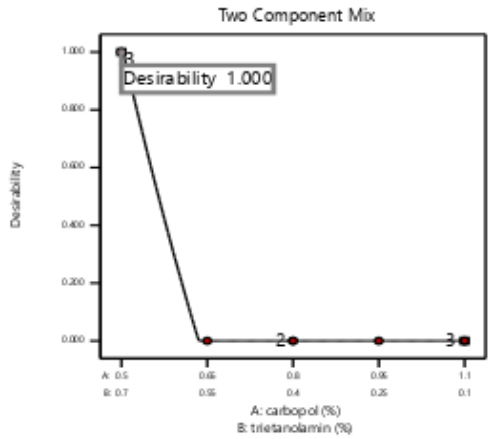

Figure 1. Graph of Variation of Two Components on Desiribilty

Verification of patchouli leaf essential oil gel optimization was carried out by creating an optimal gel formula recommended by the software and comparing the predicted response in the software with the tests carried out (actual response). Statistical test results for pH response, viscosity, spreadability and adhesion of the optimum formula, software predictions and experimental results can be seen in Table 4.

The results of the One Sample T-test statistical test between the predicted and actual responses showed that the significance value for the four actual responses was more significant than 0.05 (Table 4). This result indicates that the expected and actual responses do not differ considerably. From the results obtained, it can be concluded that the equation obtained from the software is valid. The prediction results show no difference from the experimental results and can determine the optimal formula for patchouli leaf essential oil gel with varying concentrations of the gelling agent carbopol and the alkalizing agent triethanolamine.

The stability test was carried out using the centrifugation method. This test aims to see the stability of the gel preparation after very vigorous shaking and observe whether phase separation occurs in the preparation. The centrifugation test for patchouli leaf essential oil gel was carried out by inserting the optimal formula gel into a centrifuge tube and centrifuging at a speed of 5000 rpm for 30 minutes. The centrifugal force effect exerted is equivalent to the gravitational force received by the test preparation for a year. The centrifugation test results showed that the optimal formula gel preparation did not experience phase separation. It is indicated that the gel preparation produced was stable.[20]

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Table 4. Statistical analysis (one sample T-test) of the optimal gel

Response	Prediction	Actual	Sig.(2-tailed)	Conclusion
pH	6.35694	6.29 ± 0.08	0.486	Not significantly different
Viscosity	41911.6	44086.67 ± 1510.69	0.287	Not significantly different
Stickiness	7.63889	7.62 ± 0.68	0.980	Not significantly different
Spread Power	5.52083	5.42 ± 0.08	0.332	Not significantly different

Measuring the effectiveness of sunscreen preparations is based on determining the SPF (Sun Protection Factor) value, which describes the ability of sunscreen products, including gel preparations. Determination of the SPF value of patchouli leaf essential oil gel preparations was carried out in vitro using the UV-Vis spectrophotometric method. SPF testing was carried out an optimum gel, which had been replicated three times.

The average SPF (Sun Protection Factor) value of 28.87±0.27. The SPF value category, which is more significant than 15, is classified as ultra-protection, so the optimum gel produced is in the ultra-sunscreen protection category. The higher the SPF value, the better the sunscreen ability.[24]

CONCLUSION

The optimal concentrations of carbopol and triethanolamine in patchouli leaf essential oil gel preparations are 0.5% and 0.7%. The SPF (Sun Protection Factor) value of patchouli leaf essential oil gel is 28.87±0.27, classified as ultra sunscreen protection.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

As a result, the authors declare that the work presented in this article is original and that they will bear any liability for claims relating to the content of this article.

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