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FORMULATION OF PALMAROSA (CYMBOPOGON MARTINII) ESSENTIAL OIL EMULGEL USING SODIUM CARBOXYMETHYL CELLULOSE (NA-CMC) AS A GELLING AGENT

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ABSTRACT
Palmarosa essential oil (Cymbopogon martinii) is known for its potential as a natural therapeutic agent. It contains geraniol compounds with demonstrated antimicrobial and anti-inflammatory activity. However, direct application of palmarosa essential oil to the skin is less effective and may cause irritation. Objective: This study aimed to develop a topical formulation in the form of an emulgel containing palmarosa essential oil, using sodium carboxymethyl cellulose (Na-CMC) as the gelling agent. Method: The emulgel was prepared in three different formulations containing 2%, 4%, and 6% concentrations of palmarosa essential oil. The resulting preparations were evaluated for quality through organoleptic properties, homogeneity, pH, spreadability, adhesion, and emulsion type. Data were statistically analyzed using one-way ANOVA. Results: The emulsion type test indicated that all formulations were oil-in-water (o/w) emulsions. Differences in palmarosa essential oil concentration influenced the physical properties of the emulgel, but all three formulations met the standard requirements for good physical quality of emulgel preparations.Conclusions: the three emulgel formulations containing palmarosa essential oil fulfilled the standards for acceptable physical properties

Keywords: emulgel; Na-CMC; palmarosa essential oil

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INTRODUCTION

Palmarosa (Cymbopogon martinii) is an aromatic plant known for its essential oil, which is rich in geraniol — a monoterpenoid compound reported to possess significant antimicrobial and anti-inflammatory properties (Dangol dkk., 2023). These properties make palmarosa essential oil a promising candidate for the development of natural therapeutic agents, particularly in managing skin infections and inflammatory conditions. However, direct application of essential oils to the skin can lead to irritation and poor patient compliance due to their volatility and lipophilic nature (Tisserand & Young, 2014). To overcome these limitations, the formulation of suitable topical delivery systems is crucial. Emulgels are an innovative semi-solid dosage form that combines the properties of emulsions and gels, offering advantages such as enhanced drug loading, improved stability of hydrophobic active compounds, easy application, non-greasy feel, and better patient acceptability (Susianti dkk., 2021). Emulgels are especially effective for the incorporation of lipophilic substances like essential oils into aqueous-based gel systems, thereby facilitating their safe and controlled release on the skin. The performance of an emulgel largely depends on the type and concentration of the gelling agent used. Sodium carboxymethyl cellulose (Na-CMC) is a widely utilized gelling agent in pharmaceutical formulations due to its non-toxic nature, high swelling capacity, and ability to enhance physical properties such as viscosity, spreadability, and adhesiveness (Saryanti & Putri Setyadi, 2022).

Moreover, Na-CMC can contribute to the formation of a stable emulsion within the gel matrix, which is essential for maintaining the uniform distribution of active ingredients. Based on these considerations, the present study aims to formulate and evaluate an emulgel containing palmarosa essential oil using Na-CMC as a gelling agent. The formulation will be assessed through various physical quality tests, including organoleptic evaluation, homogeneity, pH, viscosity, spreadability, adhesion, and emulsion type, in order to determine its suitability for topical use and its potential as a natural therapeutic preparation.

METHOD

1. **Extraction of Palmarosa (Cymbopogon martinii) Essential Oil**
   Palmarosa plants were harvested and extracted using the distillation method at Rumah Atsiri Indonesia, located in Tawangmangu, Central Java. The distillation process was carried out in accordance with standardized extraction procedures.
2. **Quality Testing of Palmarosa Essential Oil**
   The quality of the essential oil was evaluated based on parameters such as color, odor, and refractive index, following the Indonesian National Standard (SNI 06-3953-1995).
   a. **Organoleptic Testing of Palmarosa Essential Oil**
      Organoleptic properties, including color and odor, were assessed directly using the sense of sight and smell, in accordance with SNI 06-3953-1995.
   b. **Refractive Index Measurement of Palmarosa Essential Oil**
      A refractometer cleaned with water was prepared and maintained at a temperature within ±2°C of the reference temperature. The essential oil sample to be measured was equilibrated to the same temperature as the refractometer. A drop of palmarosa essential oil was placed onto the prism using a dropper. The prism was then closed and adjusted to obtain a sharp boundary line between light and dark fields. The reading was finalized by adjusting the dial until the intersection point of the two crosshairs aligned with the boundary line, and the refractive index was recorded from the stabilized scale (Erliyanti & Pujiastuti, 2020).
3. **Preparation of Palmarosa Essential Oil Emulgel Formulation**
   a. The formulation of the palmarosa essential oil emulgel (*Cymbopogon martinii*) was developed based on the method described by (Chandra dkk., 2023). The composition of the formulation is presented in Table 1.

Table 1.
Formulation of Palmarosa Essential Oil Emulgel

Ingredients	Formula (%)			Function
	F1	F2	F3	
Palmarosa Essential Oil	2	4	6	Active Ingredient
Sodium Carboxymethyl Cellulose (Na-CMC)	3	3	3	Gelling Agent
Tween 80	1.7	1.7	1.7	Emulsifier
Span 80	0.45	0.45	0.45	Emulsifier
Propyl Paraben	0.02	0.02	0.02	Preservative
Methyl Paraben	0.18	0.18	0.18	Preservative
Propylene Glycol	8	8	8	Humectant
Liquid Paraffin	5	5	5	Emollient
Purified Water (Aquadest)	add 100	add 100	add 100	Solvent

Notes:
F1: Emulgel containing 2% palmarosa essential oil
F2: Emulgel containing 4% palmarosa essential oil
F3: Emulgel containing 6% palmarosa essential oil

b. Preparation of Palmarosa (Cymbopogon martinii) Essential Oil Emulgel
The emulgel was prepared by first dispersing sodium carboxymethyl cellulose (Na-CMC) in hot distilled water at a ratio of 1:20 and allowing it to hydrate for 20 to 30 minutes until a gel base was formed. Methyl paraben and propyl paraben were dissolved in propylene glycol, then mixed into the hydrated gel base. An emulsion was then prepared by mixing Span 80 with liquid paraffin (oil phase) and heating the mixture to 70°C. Separately, Tween 80 was combined with part of the water (aqueous phase) and also heated to 70°C. Both phases were then combined using a magnetic stirrer until an emulsion was formed. The prepared emulsion was gradually incorporated into the gel base with continuous trituration to form the emulgel. Finally, palmarosa essential oil was added to the emulgel and mixed until a uniform and homogeneous product was obtained (Chandra dkk., 2023).

4. Quality Control of Palmarosa (Cymbopogon martinii) Essential Oil Emulgel

a. Organoleptic Evaluation and Homogeneity Test

Organoleptic characteristics were assessed visually, including the observation of form, odor, color, and texture. One gram of the formulation was placed on a glass slide for homogeneity evaluation (Wulansari dkk., 2022). Approximately 0.25 grams of emulgel was placed on a glass plate, then spread and examined by touch to identify the presence of air bubbles or granules. A topical formulation is considered homogeneous if it appears even and free from coarse particles (Saryanti & Putri Setyadi, 2022).

b. pH Measurement

The pH of each formulation was measured using a calibrated digital pH meter. Each sample was tested in triplicate. The pH meter probe was immersed in the emulgel, allowed to stabilize for a few seconds, and the pH was recorded. According to SNI 16-4399-1996, the acceptable pH range for topical emulgel preparations is 4.5 to 7.5.

c. Viscosity Test

Viscosity was measured using a Rion VT-04E viscometer. Each formulation was tested in triplicate. The sample (100 mL) was placed into a container, and the appropriate spindle was immersed to the designated mark. Once the reading stabilized, the viscosity value was recorded. According to SNI 16-4399-1996, acceptable viscosity for emulgel ranges from 2,000 to 50,000 cP (Saryanti & Putri Setyadi, 2022).

d. Spreadability Test

A 0.5-gram sample of emulgel was placed on a calibrated glass surface and left for 1 minute. The diameter of the spread was measured, followed by the sequential addition of 50, 100, 150, and 200 grams of weight. After each addition, the spread diameter was measured again. According to SNI-06-2588-1992, a good topical formulation should have a spreadability range of 5–7 cm (Saryanti & Putri Setyadi, 2022).

e. Adhesiveness Test

A 0.25-gram sample of emulgel was placed between two glass slides. A 0.5 kg weight was applied for 5 minutes. The weight was then replaced with an 80-gram load, and the time required for the two slides to separate was recorded. A gel is considered to have good adhesiveness if the adhesion time exceeds 1 second.

f. Emulsion Type Test

A mixture of 0.5 mL of methylene blue solution was added to 1 gram of each emulgel formulation (F1, F2, and F3) on a droplet plate and stirred. If the dye dissolved and dispersed evenly, the emulgel was identified as oil-in-water (o/w) type. If the dye clumped on the surface, it was considered a water-in-oil (w/o) type (Rauf dkk., 2021)

g. Data Analysis

All physical quality parameters—including organoleptic properties, homogeneity, pH, viscosity, spreadability, adhesion, and emulsion type—were evaluated for each

formulation. To determine the influence of varying concentrations of palmarosa essential oil on the physical characteristics of the emulgel, the data obtained were subjected to statistical analysis using a one-way analysis of variance (ANOVA). This method was applied to assess whether the differences observed among formulations were statistically significant.

RESULT

Quality Test Results of Palmarosa Essential Oil

The quality assessment of palmarosa essential oil included evaluation of its color, odor, and refractive index. The results are presented in table 2.

Table 2.
Quality Evaluation of Palmarosa Essential Oil

Parameter	SNI 06-3953-1995	Replication 1	Replication 2	Replication 3
Color	Pale yellow	Pale yellow	Pale yellow	Pale yellow
Odor	Characteristic aroma	Palmarosa-like	Palmarosa-like	Palmarosa-like
Refractive Index	1.466 – 1.475	1.471	1.471	1.471

Physical Characteristics of Emulgel Formulations

Organoleptic Evaluation

Organoleptic testing included evaluation of physical form, color, odor, and texture, as presented in table 3.

Table 3.
Organoleptic Test Results of Palmarosa Essential Oil Emulgel

Characteristics	Formula 1 (2%)	Formula 2 (4%)	Formula 3 (6%)
Form	Semi-solid	Semi-solid	Semi-solid
Odor	Characteristic palmarosa	Characteristic palmarosa	Characteristic palmarosa
Color	White	White	White
Texture	Thick	Thick	Thick
Homogeneous	Homogeneous	Homogeneous	Homogeneous

pH test

The pH testing is an important parameter in the quality evaluation of topical preparations, as appropriate pH values help prevent irritation and maintain the balance of the skin's microbiota. The results are presented in Table 4.

Table 4.
pH Values of Palmarosa Essential Oil Emulgel

	Formula 1 (2%)	Formula 2 (4%)	Formula 3 (6%)
Replication 1	5.7	5.5	5.0
Replication 2	5.7	5.5	5.4
Replication 3	6.1	6.0	5.7
Mean ± SD	5.83 ± 0.19	5.67 ± 0.24	5.37 0.29

Viscosity Test

Viscosity is an important parameter in the formulation of topical preparations such as emulgel, as it affects physical stability, ease of application, and user comfort. The viscosity test results can be seen in Table 5.

Table 5.
Viscosity of Palmarosa Essential Oil Emulgel

	Formula 1 (cP)	Formula 2 (cP)	Formula 3 (cP)
Replication 1	3100	2900	2700
Replication 2	3000	2900	2700
Replication 3	3100	2800	2800
Mean ± SD	3066.67 ± 47.14	2866.67 ± 47.14	2733.33 ± 47.14

Spreadability Test

Spreadability is a critical parameter that reflects the ability of a topical preparation to spread over the skin surface. The results of the spreadability test can be seen in Table 6.

Table 6.
Spreadability of Palmarosa Emulgel

	Formula 1 (cm)	Formula 2 (cm)	Formula 3 (cm)
Replication 1	5.15	5.30	5.75
Replication 2	5.15	5.35	6.00
Replication 3	5.30	6.00	6.15
Mean ± SD	5.20 ± 0.07	5.55 ± 0.32	5.97 ± 0.16

Adhesiveness Test

Adhesiveness is a crucial parameter for topical preparations, reflecting the ability of a formulation to remain on the skin surface for a specific period. The results of the adhesion test can be seen in table 7.

Table 7.
Adhesiveness of Palmarosa Essential Oil Emulgel

	Formula 1 (s)	Formula 2 (s)	Formula 3 (s)
Replication 1	3.81	3.25	2.93
Replication 2	2.94	2.79	2.78
Replication 3	3.64	3.22	3.16
Mean ± SD	3.46 ± 0.38	3.09 ± 0.21	2.96 ± 0.16

Emulsion Type Test

Emulsion type was determined using methylene blue dye. All formulations showed even dye distribution, indicating oil-in-water (o/w) emulsion type. The results of the emulsion type test can be seen in table 8.

Table 8.
Emulsion Type Test of Palmarosa Essential Oil Emulgel

Formula	Emulsion Type
F1	Oil-in-water (o/w)
F2	Oil-in-water (o/w)
F3	Oil-in-water (o/w)

DISCUSSION

Quality Test Results of Palmarosa Essential Oil

The color of palmarosa essential oil used in this study was consistently light yellow across all three replications, which complies with the requirements of SNI 06-3952-1995, namely pale yellow. This light yellow color is attributed to monoterpene and sesquiterpene derivatives such as geraniol, the major component of palmarosa essential oil (Puspitasari et al., 2022). The appearance of this color also indicates that no significant degradation due to oxidation or excessive heat occurred during distillation or storage. Odor testing showed a consistent characteristic palmarosa aroma in all replications. This distinctive fragrance results from geraniol, which imparts a floral rose-like scent and is the signature compound of palmarosa essential oil. The presence of this typical scent, without any rancid or off-odor, confirms that the essential oil remains fresh and has not undergone notable oxidation (Amalia et al., 2021). This is especially important in cosmetic or topical formulations as organoleptic properties significantly influence user comfort and acceptance. The measured refractive index was 1.471 for all three replications, which falls within the standard range of 1.466–1.475 according to SNI 06-3952-1995. This value indicates good purity and consistent composition of the essential oil. Refractive index is a critical physical parameter in assessing the consistency and purity of essential oils because it is influenced by carbon chain length, unsaturation levels,

and molecular interactions (Sari et al., 2023). A stable refractive index suggests the essential oil is of good quality and suitable for formulation into emulgel preparations.Based on the standard requirements of SNI 06-3953-1995, the palmarosa essential oil used in this study met the specifications for color and odor (pale yellow color and characteristic palmarosa scent) as well as refractive index.

Physical Characteristics of Emulgel Formulations

Organoleptic Evaluation

The organoleptic evaluation aimed to assess the physical characteristics of the preparation, including form, color, odor, and texture. Based on the organoleptical observations shown in table 3, that all emulgel formulations (Formula 1: 2%, Formula 2: 4%, and Formula 3: 6% palmarosa essential oil) exhibited a semi-solid form, white color, characteristic palmarosa odor, and thick texture. The increase in the concentration of essential oil did not result in significant changes in these organoleptic parameters. Organoleptic evaluation is an important preliminary step to ensure the quality and consistency of topical preparations. According to Utami et al., (2023), organoleptic assessment can reflect the stability and suitability of a formulation in accordance with expected quality standards. The homogeneity test was conducted to ensure even distribution of the active component throughout the preparation. In this test, samples from each formula were visually observed on a glass plate with a black background. The results showed that all emulgel formulations were homogeneous, with no visible coarse particles. Good homogeneity is essential to ensure the effectiveness and safety of topical preparations. A study by Rinaldi et al., (2021) emphasized that consistent homogeneity in topical formulations ensures an even distribution of active ingredients, which is crucial for optimal therapeutic performance.

pH Test

Normal human skin has a physiological pH ranging between 4.5 and 6.5 as outlined by SNI 16-4399-1996. Topical preparations with pH values outside this range may cause skin irritation, reduce the effectiveness of the skin's natural barrier, and disrupt normal skin flora (Lambers et al., 2006; Rogiers, 2001). The pH measurements of the palmarosa essential oil emulgel formulas shown in table 4, that all formulations remained within the physiological range. There was a noticeable trend of decreasing pH with increasing concentrations of palmarosa essential oil. This decline is likely due to the chemical composition of the essential oil, which contains active compounds such as geraniol, linalool, and citronellol. Geraniol, the major constituent, possesses hydroxyl groups that may contribute to the weak acidity of the system, resulting in a lower pH at higher concentrations (Bakkali et al., 2008). The decrease in pH between Formula 1 and Formula 3 is not drastic and remains within a safe range for topical application. The relatively small standard deviations for each formula indicate that the emulgel system was homogeneous and stable in terms of pH. From a dermatological perspective, formulations with pH values between 5.3 and 5.8—such as those observed in this study—are considered safe and compatible with the skin's natural pH. Therefore, it can be concluded that increasing the concentration of palmarosa essential oil up to 6% still results in a stable and topically acceptable formulation.

Viscosity Test

An emulgel with optimal viscosity ensures stability during storage, spreads easily upon application, and does not flow away from the intended application site. The viscosity measurements of three palmarosa essential oil emulgel formulations shown in table 5, a decrease in viscosity as the concentration of essential oil increased. All three formulations used the same concentration of the gelling agent (Na-CMC) at 3%, which is known to produce high viscosity due to its ability to form a gel matrix through hydrogen bonding and

intermolecular interactions. (Chirilă et al., 2024). However, the increasing concentration of palmarosa essential oil appears to affect the gel network, leading to reduced viscosity. Essential oils are lipophilic and can interfere with the hydrogen bonding between polymer chains in the hydrophilic continuous phase (Shakeel, 2021). Compounds such as geraniol, a major component of palmarosa essential oil, may reduce viscosity by disrupting the three-dimensional gel network—especially at higher concentrations (Wani, 2024). Additionally, increasing the oil phase may alter the internal distribution of the emulgel system and induce microphase separation or reduce the compactness of the structure, which contributes to lower viscosity. Nonetheless, all formulations still fall within an acceptable viscosity range for topical application (2500–3500 cP), ensuring they are suitable for dermal use. The low standard deviation (±47.14) across all formulations also indicates consistent replicates and good formulation stability. As shown in Table 6, all formulations fell within the acceptable viscosity range of 2,000–50,000 cP (SNI 16-4399-1996). All formulations met the requirements for good viscosity, supporting formulation stability (Baskara et al., 2020).

Spreadability Test

Good spreadability enhances user comfort, facilitates efficient absorption of the active ingredient, and allows easy application without the need for excessive pressure. The data shown on table 6, a gradual increase in spreadability as the concentration of palmarosa essential oil increases in the formulation. This is likely associated with a corresponding reduction in viscosity observed in formulations with higher essential oil concentrations. Lower-viscosity emulsions tend to have a looser structure, making them easier to spread when pressure is applied. Although all formulas used the same amount of Na-CMC (3%) as the gelling agent, the increased concentration of lipophilic essential oil appears to weaken the hydrophilic gel network. This results in lower viscosity and a softer emulgel texture, which directly contributes to increased spreadability. In addition, components like liquid paraffin (emollient) and propylene glycol (humectant)—present in equal concentrations across all formulations—also contribute to lubrication and enhance the spreadability of the emulgel. However, the observed differences are more likely influenced by the variation in essential oil concentration, which can interfere with the gel structure as an active component. This finding aligns with previous studies which observed that increasing the concentration of essential oils in emulgel formulations leads to a reduction in viscosity and enhances spreadability (Andriani & Amin, 2023; Sundari & Puspitasari, 2024). The standard deviation for Formula 2 (±0.32) is slightly higher than the others, possibly due to more complex interactions between the emulsion and oil phases at the intermediate concentration. Nevertheless, all formulations demonstrate spreadability values within the acceptable range for topical preparations, typically around 5–7 cm, as suggested by various formulation studies (Rauf dkk., 2021). ANOVA results showed a significant difference among the three formulations ($p = 0.031 < 0.05$), indicating that essential oil concentration affected spreadability, though all values remained within the optimal range.

Adhesiveness Test

Optimal adhesiveness can enhance therapeutic efficacy by allowing the active compound to stay longer at the application site and preventing the preparation from being easily removed by friction or skin movement. The data shown on table 7, that an increase in the concentration of palmarosa essential oil tends to reduce the adhesiveness of the formulation. This decrease may be attributed to the lipophilic nature of essential oils, which can disrupt the hydrophilic gel network formed by Na-CMC. When the gel structure is weakened, the formulation's ability to maintain adhesive interactions with the skin surface also decreases (Tiwari et al., 2020). Additionally, the decrease in viscosity observed with increasing essential oil content also contributes to reduced adhesiveness. Lower-viscosity formulations typically have a

looser structure and weaker molecular interactions, making them less capable of maintaining prolonged contact with the skin surface (Shakeel et al., 2019). Despite the reduction in adhesiveness, all formulations remain within the acceptable range for topical preparations, which is approximately 2–5 seconds. The low standard deviation values also indicate that the results were consistent across replications, suggesting good formulation stability. Statistical analysis confirmed that the data were normally distributed ($p > 0.05$) and homogeneous ($p = 0.089 > 0.05$). ANOVA results indicated significant differences between groups ($p = 0.000 < 0.05$), showing that essential oil concentration significantly influenced adhesiveness.

Emulsion Type Test

The emulsion type test aimed to identify whether the emulgel formulations of palmarosa essential oil were of the oil-in-water (o/w) or water-in-oil (w/o) type. The test was conducted using methylene blue dye, which is hydrophilic and dissolves in water. Uniform distribution of the dye in the emulgel indicates that water is the continuous phase, thus confirming an o/w emulsion type. All three formulations—F1 (2%), F2 (4%), and F3 (6%)—exhibited oil-in-water (o/w) emulsion characteristics. This is advantageous for topical products, as o/w emulsions are non-greasy, easily washable, and generally more comfortable upon application. Furthermore, o/w emulsions can enhance the release of lipophilic active ingredients into the skin, as the aqueous continuous phase facilitates better diffusion and bioavailability (Kute, 2023). The stability of the o/w emulsion system was supported by the use of Tween 80 and Span 80 as emulsifiers. Tween 80, a hydrophilic surfactant, stabilizes the aqueous phase, while Span 80, which is more lipophilic, stabilizes the oil phase. When combined in appropriate ratios, they produce a balanced hydrophilic-lipophilic system that promotes the formation of a stable o/w emulsion (Jain, 2023). The inclusion of Na-CMC as a gelling agent further enhances the stability of the emulsion by increasing the viscosity of the system and preventing oil droplet coalescence. In addition, recent work by Tăbăcaru, (2024) has shown that o/w emulsions incorporated with palmarosa essential oil can be successfully stabilized for dermal applications using biocompatible polymers and emulsifier systems. These findings support the results observed in this study. Thus, the use of appropriate emulsifiers and gelling agents in this formulation successfully produced stable o/w emulgel systems suitable for topical delivery of essential oils. The methylene blue dye dissolved uniformly in all samples, confirming the o/w emulsion type (Rinaldi et al., 2021)

CONCLUSION

Statistical analysis (ANOVA) confirmed significant effects of essential oil concentration on spreadability and adhesiveness, while all other parameters showed consistent performance across replications with low standard deviations. Overall, the study concludes that emulgel formulations containing up to 6% palmarosa essential oil are physically stable, dermatologically acceptable, and possess appropriate characteristics for use as topical dosage forms.

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