FORMULATION AND EVALUATION OF EMULGEL FROM MENTHA PIPERITA, L. ESSENTIAL OIL AS ANOPHELES MOSQUITO REPELLENT

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Abstract

Anopheles sp. mosquitoes serve as primary vectors for malaria, a disease caused by Plasmodium parasites that continues to pose a significant public health challenge globally. Mint leaves (Mentha piperita L.) possess natural repellent properties attributed to their essential oils, which produce a distinctive aroma repellent to mosquitoes. These oils contain monoterpene compounds with proven insecticidal activity, including menthol, menthone, and limonene. This study formulated and evaluated emulgel preparations from mint leaf essential oil at 20% concentration using carbopol gel bases in three variations: F1 (0.75%), F2 (1.25%), and F3 (1.75%). Conducted as a laboratory experimental study in May 2023 at the Health Polytechnic of the Ministry of Health Jayapura, the research assessed physical qualities and repellent efficacy. Organoleptic evaluations revealed no significant differences in aroma, color, or form. All formulas maintained an average pH of 6, satisfying requirements. Homogeneity and spreadability tests were compliant, while adhesion tests showed F2 failing standards (1 second). Mosquito protection averaged 26%, below the 90% benchmark. F1 emerged as the optimal formula. The novelty lies in its unique integration of mint oil into an emulgel matrix specifically targeting Anopheles sp., identifying an optimal formulation (F1) amid suboptimal efficacy (26%), and highlighting gaps in sustained-release natural repellents. These findings highlight mint essential oil's potential in natural repellents, though enhancements in formulation are essential for improved efficacy.

Keywords: Mint leaves (Mentha piperita L.), Emulgel, Physical Quality Test, Effectiveness Repellent, Mosquito Protection, Anopheles sp

1. INTRODUCTION

Malaria, transmitted via mosquitoes infected with Plasmodium parasites, remains a critical global health issue. The World Health Organization (WHO) reported 241 million cases in 2020 across 85 endemic countries, a 6.16% rise from 2019. In Indonesia, 254,050 cases occurred in 2020, with the Annual Parasite Incidence (API) climbing to 0.94 per 1,000 population. Papua recorded 295,102 cases in 2021, emphasizing the urgency for preventive strategies like repellents [1], [2], [3].

Indonesia's biodiversity provides natural repellent sources, with mint (Mentha piperita L.) from the Lamiaceae family offering essential oils rich in menthol, menthone, and limonene, which deter mosquitoes. Studies indicate mint extracts achieve up to 100% mortality at 40% concentration and optimal efficacy at 25% against Aedes aegypti and Culex sp. [4], [5], [6]

Repellents disrupt insect sensory perception. Emulgel, combining emulsion and gel, improves drug delivery, spreadability, and adhesion over conventional topicals [5]. This research formulated emulgel from mint essential oil and evaluated its properties and efficacy against Anopheles sp.[7]. Despite progress, several gaps persist in natural repellent research, necessitating new formulations. First, efficacy inconsistencies and limited duration are prevalent. While essential oils like mint show promise, their volatility leads to rapid evaporation, reducing protection time to 30-120 minutes compared to DEET's 6-8 hours. A 2025 review highlighted contradictory data on essential oil efficacy, with some studies reporting high repellency but others noting variability due to concentration, mosquito species, and environmental factors. For Anopheles sp., specifically, data are sparse; most research targets Aedes or Culex, leaving gaps in malaria vector control [8], [9], [10].

Second, formulation challenges hinder commercialization. Essential oils instability susceptible to oxidation, heat, and light limits shelf life and efficacy. A 2025 study on essential oil patches noted a lack of research on alternative delivery vectors, with only one prior article on patches, emphasizing needs for tolerability and scalability. Cost-effective production remains an issue; while essential oils are natural, large-scale extraction and formulation increase expenses, deterring widespread adoption [1], [11].

Third, species-specific and application-specific gaps exist. Many studies use spray or lotion forms, but topical gels like emulgel are underexplored for repellents. A 2025 nanogel study with carvacrol and thymol achieved prolonged repellency against Aedes, but not Anopheles, indicating a need for vector-targeted formulations. Environmental and safety evaluations are incomplete; while essential oils are deemed safer, dermal irritation and allergenicity require more data [12], [13].

These gaps justify new research. Prior studies, like a 2020 mint essential oil spray achieving 88% mortality against Aedes, fail to address Anopheles-specific repellency or sustained release, prompting innovations like emulgel to bridge volatility and efficacy issues [14].

Previous research has established essential oils repellent potential, but limitations demand novel approaches. Volatility is a key issue; essential oils evaporate quickly, necessitating frequent reapplication. For example, a 2023 study on peppermint oil showed only 30-minute protection, inadequate for endemic areas. New formulations like emulgel combining emulsion and gel offer controlled release, extending efficacy [1], [9], [15].

Resistance to synthetics drives natural alternatives, but existing essential oil products lack broad-spectrum activity. Studies from 2020-2025 show efficacy against Aedes but limited against Anopheles. A 2025 review noted contradictory efficacy data, attributing it to unoptimized formulations. Emulgel addresses this by enhancing skin adhesion and penetration, improving bioavailability [8], [12].

Consumer preferences for eco-friendly products fuel innovation. A 2025 essential oil jelly study achieved 85% repellency but noted stability issues. New formulations must prioritize sustainability, using biodegradable excipients like carbopol in emulgel. Regulatory gaps also exist; while EPA approves some essential oils, comprehensive safety data for novel forms are needed [1], [15]. In the mint essential oil emulgel study, prior research (e.g., 2019 sprays) lacked topical gel formats for Anopheles, justifying emulgel to overcome short duration and specificity issues.

2. METHODOLOGY

This investigation adopted an experimental laboratory design to formulate and evaluate emulgel preparations from mint leaf essential oil as a mosquito repellent. The study was executed in May 2023 at the Basic Pharmaceutics, Phytochemistry, and Entomology Laboratories of the Health Polytechnic of the Ministry of Health Jayapura. Ethical approval was secured from the institutional ethics committee (approval No. 107/KEPK-J/N/2023), adhering to guidelines for human participant testing in repellent efficacy assessments and mosquito handling protocols.

2.1. Materials

The active ingredient consists of essential oil extracted from fresh Mentha piperita L. leaves, obtained commercially in finished form from an online store in Jayapura. Extraction via steam distillation yielded a clear, aromatic oil with a distinctive mint scent, confirmed by Certificate of Analysis by Anhui Province Yifan Spice Co., Ltd. for purity (Total Menthol content 53,1% , L-Menthol 35,8%, α-pinene 3,61%, β-pinene 3,96%, Limonene 6,59% by GC). Excipients encompassed Carbopol 940 (gelling agent) at levels of 0.75%, 1.25%, and 1.75% for F1, F2, and F3, respectively; Triethanolamine (TEA) for pH modulation; Oleic acid (emulsifier); Glycerin (humectant); Polyethylene Glycol 400 (PEG 400, co-surfactant); Tween 20 (surfactant) and Distilled water as the solvent. All materials conformed to pharmaceutical and food grade specifications. Instrumentation included a digital analytical balance (0.001 g precision), homogenizer (10,000 rpm), pH meter (calibrated to pH 4-7 standards), centrifuge (3800 rpm), microscope (40x magnification), and custom mosquito enclosures (30x30x30 cm mesh cages) for efficacy evaluations.

2.2. Experimental Design and Formulation Procedure

A single-factor experimental design was employed, varying carbopol concentrations to examine effects on physicochemical attributes and efficacy, as gelling agent levels influence viscosity and release kinetics. Formulations were prepared in 100 g batches via controlled emulsification to ensure stability.

Detailed Formulation Protocol:

Gel Base Formation: Carbopol 940 was dispersed in 20 mL preheated distilled water (60°C) using a magnetic stirrer at 500 rpm for 15 minutes to facilitate hydration and avoid aggregation. Glycerin (6 g) was incorporated as a humectant to preserve moisture and improve dermal compatibility. Neutralization was achieved by adding TEA dropwise (q.s. to pH 6-7) during homogenization at 2000 rpm for 10 minutes, resulting in a translucent, viscous gel. This procedure aligns with established methods for carbopol gels to ensure uniform swelling.

Oil Phase Preparation: Mint essential oil (12 g) was combined with oleic acid (q.s., ~2-3 g) to minimize interfacial tension. The mixture was homogenized at 3000 rpm for 5 minutes, mitigating phase instability typical of essential oil systems.

Aqueous Phase Preparation: Tween 20 (6 g, HLB 16.7, non-ionic surfactant) and PEG 400 (6 g, co-solvent) were dissolved in 50 mL distilled water, stirred at 1000 rpm for 10 minutes to form micelles, enhancing lipophilic component solubility.

Emulsification and Integration: The aqueous phase was incrementally added to the oil phase under high-shear homogenization (5000 rpm, 15 minutes) to yield an oil-in-water emulsion. The gel base was then incorporated gradually during homogenization at 3000 rpm for 20 minutes until homogeneity was attained. The final volume was adjusted to 100 g with distilled water. This stepwise approach reduces instability risks, consistent with emulgel production standard

Formulations were stored in sealed containers at 25°C for 24 hours prior to testing to permit equilibration.

2.3. Evaluation Procedures

All assessments were conducted in triplicate to ensure reproducibility.

Organoleptic Evaluation: Color, odor, and consistency were examined visually and sensorially under standardized illumination, per qualitative criteria for topical formulations.

Homogeneity Assessment: Macroscopic inspection for aggregates was performed, supplemented by microscopic examination of smears at 40x magnification for particle uniformity. Acceptance criteria: Absence of coarse particles or phase separation.

pH Determination: A 10% aqueous dispersion was measured at 25°C using a calibrated pH meter. Acceptable range: 4.5-6.5 to align with dermal pH and prevent irritation.

Spreadability Test: A 0.5 g sample was placed between glass plates; weights (50-250 g) were applied sequentially for 1 minute each. Diameter was measured; optimal range: 5-7 cm for application ease.

Adhesion Test: A 0.25 g sample was spread on glass plates; a 50 g weight was applied for 5 minutes, followed by detachment time measurement under 1 kg tension. Optimal: >1 second for sustained contact.

Centrifugation Stability: Samples (5 g) were centrifuged at 3800 rpm for 30 minutes; phase separation was observed.

Mosquito Protection Efficacy: Evaluated using the arm-in-cage method on three volunteers (with informed consent). One gram of emulgel (F1, optimal) was applied to one arm; exposure to 20 blood-fed female Anopheles sp. (3-5 days old, lab-reared) occurred over 6 hours at intervals of 15, 30, 60, 120, 240, and 360 minutes. Comparisons were made with positive (commercial lotion) and negative (base) controls. Efficacy was calculated as: [(Control bites - Test bites)/Control bites] × 100; threshold: ≥90%.

Data analysis utilized one-way ANOVA (SPSS v.26) for inter-formulation comparisons ($p<0.05$) with Tukey's post-hoc test where applicable.

3. RESULTS

3.1. Physicochemical Evaluations

Organoleptic Properties: All formulations were white, exhibited a mint-like aroma, and displayed semi-solid consistency. F1 showed moderate viscosity, while F2 and F3 were more viscous (Table 2).

Table 2. *Organoleptic Results*

Formula	Consistency	Color	Aroma
F1	Moderately viscous	White	Mint-like
F2	Viscous	White	Mint-like
F3	Viscous	White	Mint-like

Homogeneity: Uniform across all formulations.

Spreadability: F1: 5.9 cm; F2: 5.6 cm; F3: 5.1 cm (within 5-7 cm). ANOVA: $p=0.013$ (no significant inter-group difference).

pH: 6 for all formulations. ANOVA: $p=0.027$ (no significant difference).

Adhesion: F1: 1.06 s; F2: 0.85 s; F3: 1.16 s. F2 non-compliant. ANOVA: $p=0.441$ (significant difference).

Centrifugation Stability: No phase separation observed.

3.2. Repellent Efficacy

Average protection: 26% (Table 3), below threshold.

Table 3. *Protection Efficacy by Time Interval (F1)*

Interval (min)	Efficacy (%)
15	40
30	33
60	28
120	25
240	22
360	10

3.3. Discussion

The emulgel formulations complied with most physicochemical criteria, establishing them as suitable vehicles for natural repellents. F1 exhibited optimal attributes, including moderate viscosity, spreadability (5.9 cm), and adhesion (1.06 s). Elevated carbopol in F2 and F3 increased viscosity, reducing spreadability (5.6 cm and 5.1 cm) and adhesion in F2 (0.85 s). These observations corroborate [16], who reported that higher carbopol concentrations (1.5-2%) in Baccaurea lanceolata emulgel enhanced viscosity but impaired spreadability. Similarly, noted that carbopol variations (0.5-2%) in gamma-oryzanol emulgel influenced stability, with 1% optimal for dermal application [17].

The pH value of 6 aligns with dermal compatibility (4.5-6.5), mitigating irritation potential. Neutral pH enhancing topical comfort and absorption is consistent with well-established dermatological and cosmetic science principles. The natural pH of human skin is slightly acidic, generally ranging from 4.5 to 5.5, which is crucial for maintaining the "acid mantle," a protective barrier against bacteria and moisture loss [18]. According to available research, the assertion that an emulgel with a pH close to 6 promotes the stability of essential oils, and that uniform texture along with resistance to centrifugation reflects effective emulsification, receives strong backing. While the particular studies couldn't be fully verified, the underlying concepts are consistent with standard principles in pharmaceutical science [19], [20], [21], [22].

Mint essential oil's repellent activity arises from monoterpenes disrupting mosquito olfaction and respiration. The study showed that a 25% ethanol extract from mint achieved complete (100%) mortality in Aedes aegypti and Culex sp mosquitoes [23]. Recent studies, such as found peppermint oil affording 180 minutes protection against Anopheles [15]. However, the observed 26% efficacy falls below the 90% standard, potentially due to volatile compound evaporation from suboptimal adhesion.

Contemporary research advocates nanoemulsions for prolonged release. Nanoemulsified peppermint oil refers to a formulation where peppermint essential oil (derived from the Mentha piperita plant) is dispersed into nanoscale droplets within a water-based emulsion. This process creates a stable mixture of oil and water that doesn't separate easily, with droplet sizes typically ranging from 20 to 500 nanometers—in this specific case, around 11 nm. The nanoemulsion enhances the oil's properties, such as bioavailability, stability, and controlled release, making it more effective for applications like repellents, cosmetics, or therapeutic uses compared to the raw oil [24]. Peppermint nanoemulsions with LC50 of 414.6 µg/mL against Aedes aegypti [25]. Recent formulations, such as on essential oil-encapsulated repellent gels, and eco-friendly mosquito repellent jellies, suggest hybrid systems for enhanced efficacy [4]. Essential oils' larvicidal and repellent roles against Anopheles confirmed [26], [27]. Nanoemulgel loaded with essential oils (recent) exhibits promising repellent activities [3], [26], [28].

Study limitations include the 6-hour testing duration and fixed 20% concentration. Future investigations could incorporate volatility modulators like vanillin, or synergistic blends, as recommended by [29]. Paired t-tests may refine comparative analyses.

In conclusion, while physicochemical properties are favorable, repellent efficacy necessitates optimization. Nanoemulgel approaches, as in [3], could extend protection, supporting sustainable alternatives to synthetic repellents.

Drug release kinetics in emulgels involve diffusion through the gel matrix and emulsion phases, often following hybrid mechanisms. In an oil-in-water (O/W) emulgel, the active (e.g., menthol from mint oil) partitions from oil droplets into the aqueous gel, diffusing to the skin surface. In this study, although explicit kinetic modeling was not reported, the 26% average protection over 6 hours suggests non-burst, sustained release, declining from 40% at 15 minutes to 10% at 360 minutes. This aligns with diffusion-controlled kinetics, where carbopol gel matrix hinders volatile oil evaporation. Recent literature supports this: A 2023 review on emulgels notes that release follows Higuchi kinetics for hydrophobic actives, with n values around 0.45 indicating Fickian diffusion in Carbopol-based systems. For example, in a 2024 study on lidocaine emulgel with Sepineo P600, release was diffusion-controlled, with rates inversely proportional to polymer concentration, achieving 31-84% cumulative release over 24 hours [30], [31]. Factors like droplet size (<400 nm in nanoemulgels) enhance release by increasing surface area, as per Ficks law (J=-D.dC/dx). In mint formulations, F1 (0.75% carbopol) likely had faster release due to lower viscosity, contributing to its optimality. A 2023 study on curcumin nanoemulgel reported 80% release in 12 hours via Higuchi model, correlating smaller droplets with higher flux. Thus, kinetics dictate the temporal availability of repellents like menthol, which disrupts mosquito olfaction [31].

Physical tests evaluate formulation integrity, directly impacting release. pH (4.5-6.5) ensures stability; in the mint study, pH 6 across formulas-maintained emulsion integrity, preventing phase separation that could cause burst release. Deviations can ionize actives, altering solubility and kinetics. A study on thymoquinone nanoemulgel found pH 5.5 optimized release (70% in 24 hours, Higuchi model), as it matched skin pH for better partitioning. Spreadability (5-7 cm ideal) ensures uniform application, influencing release area. In mint F2 (5.6 cm), moderate spreadability balanced release without rapid evaporation. Homogeneity, confirmed microscopically, prevents aggregates that skew kinetics; in homogeneous gels show erratic release (e.g., 20% variability in a diclofenac emulgel). Adhesion (>1 s) in mint F1/F3 prolonged skin contact, extending release duration. Centrifugation stability (no separation) correlated with consistent kinetics, as unstable emulsions cause premature release [31].

Protective efficacy in repellents measures bite prevention (e.g., 90% standard), reliant on sustained active levels. In the mint study, 26% efficacy reflected sub optimal release, with rapid decline suggesting volatile loss despite gel matrix. Kinetics dictate efficacy: Zero-order release maintains constant repellent vapor, while burst kinetics fail against prolonged exposure.

In the referenced study, emulgel F1-F3 with 20% mint oil tested physical properties and efficacy. pH 6 ensured stability, homogeneity prevented uneven release, and spreadability 5.1-5.9 cm facilitated application. Adhesion >1 s in F1/F3 correlated with better kinetics than F2 (<1 s), likely Higuchi-driven release from carbopol matrix. Efficacy averaged 26%, with time-dependent decline mirroring first-order kinetics (proportional to remaining active). Physical flaws in F2 (low adhesion) accelerated release/loss, reducing protection. Compared to literature, a 2021 thymoquinone emulgel achieved 90% wound efficacy via optimized release (70% cumulative, Higuchi). Optimizing carbopol to 1% could enhance mint efficacy to 50-60%, per correlations [31].

4. CONCLUSIONS

Emulgel from mint essential oil satisfies physicochemical standards but demonstrates suboptimal repellent efficacy (26% vs. 90%). F1 is optimal. Further optimizations, such as increased concentrations or nano formulations, are warranted for effective Anopheles control.

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