

The Efficacy of *Eucalyptus globulus* Labill Leaf Extract in Controlling Ectoparasites: A Natural Alternative Pest Control for *Pediculus humanus capitis*

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Abstract: Head lice (*Pediculus humanus capitis*) infestation is a widespread public health concern, particularly among school-aged children, causing itching, discomfort, and social distress. Conventional chemical pediculicides, such as permethrin, are commonly used; however, increasing reports of lice resistance, potential side effects, and high treatment costs have driven interest in natural, alternative remedies. This study aimed to evaluate the pediculicidal efficacy of *Eucalyptus globulus* Labill. leaf essential oil and compare it with permethrin and distilled water using an in vitro experimental design. Freshly harvested eucalyptus leaves were dried and subjected to steam distillation, yielding 4.5 mL of pure essential oil. A total of 35 live adult lice were randomly assigned to treatment groups and exposed to three different volumes of essential oil (1.0 mL, 1.5 mL, and 2.0 mL). Permethrin served as the positive control, and distilled water as the negative control. Lice mortality was monitored and recorded at fixed time intervals. Results demonstrated that all concentrations of *Eucalyptus globulus* Labill essential oil achieved 100% mortality within 12 minutes, with the highest volume acting most rapidly. Permethrin achieved 100% mortality within 3 minutes, confirming its efficacy, while distilled water showed no pediculicidal effect. The findings indicate that *Eucalyptus globulus* Labill essential oil is a potent, natural, and accessible alternative for the treatment of head lice, offering a promising option for communities seeking safer and cost-effective remedies. Further research is recommended to explore its practical application in vivo and to investigate potential mechanisms of action.

Keywords: *Eucalyptus globulus* Labill Essential Oil, Head Lice, *Pediculus humanus capitis*, Permethrin, Natural Alternative.

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I. INTRODUCTION

Human head lice infestation, caused by *Pediculus humanus capitis*, is one of the most widespread parasitic conditions affecting humans worldwide. This obligate ectoparasite lives exclusively on the human scalp and depends entirely on human blood for survival. Unlike many other parasites, head lice cannot survive for extended periods away from their host, making direct human-to-human contact the primary mode of transmission. Despite advancements in hygiene, medicine, and public health systems, pediculosis capitis continues to affect millions of individuals annually,

particularly school-aged children. The condition transcends geographic, socioeconomic, and cultural boundaries, occurring in both developed and developing nations. Its persistence over time highlights the complexity of managing infestations and underscores the need for improved preventive and therapeutic strategies.

The growing concern over resistance to conventional chemical pediculicides, such as permethrin, along with their potential side effects, has spurred interest in natural alternatives. Plant-derived essential oils, rich in bioactive compounds, have demonstrated insecticidal properties and

may provide a safer, eco-friendly approach to lice control. In particular, *Eucalyptus globulus* Labill essential oil has shown promising pediculicidal effects in laboratory settings, suggesting its potential as an effective, accessible, and sustainable option for managing head lice infestations, especially in communities with limited access to conventional treatments.

Head lice are small, wingless insects measuring approximately 2–4 mm in length. They possess specialized claws that enable them to grasp hair shafts securely, allowing them to move efficiently within the scalp environment. Female lice lay eggs, known as nits, which are firmly attached to the base of hair strands using a glue-like substance. These eggs typically hatch within 7–10 days, releasing nymphs that mature into reproductive adults within another 7–10 days. Under favorable conditions, the life cycle can be completed in approximately three weeks, permitting rapid population expansion if infestations are not promptly addressed. Adult lice feed several times daily by piercing the scalp to obtain blood, injecting saliva that contains anticoagulant and immunogenic substances. It is this salivary secretion that triggers itching and inflammation in sensitized individuals.

Transmission occurs primarily through direct head-to-head contact, which is common among children during play, classroom activities, sports, and social interactions. Because young children frequently engage in close physical proximity, they are particularly vulnerable to acquiring and spreading lice. Although indirect transmission via shared personal items such as combs, hairbrushes, hats, scarves, headphones, pillows, and towels is possible, it is generally considered less common. Lice survives for only a short duration away from the scalp, and eggs require the warmth of the human head to develop successfully. Nevertheless, in densely populated settings or households with limited resources, indirect transmission may contribute to persistent infestation cycles.

Globally, prevalence rates vary considerably depending on region, climate, population density, and socioeconomic conditions. Studies have reported prevalence ranging from less than 5% to more than 40% among school-aged children in certain communities. Warm and humid climates may facilitate lice survival, while crowded living conditions enhance transmission opportunities.

In low- and middle-income countries, limited access to healthcare, inadequate health education, and insufficient preventive measures further exacerbate the problem. However, pediculosis capitis is not restricted to economically disadvantaged populations. Outbreaks are frequently documented in private schools and affluent communities, demonstrating that head lice infestation is not solely a reflection of poor hygiene or poverty. Misconceptions linking lice to uncleanness contribute to stigma and may delay appropriate treatment.

In the Philippines, head lice infestation remains a notable public health issue, particularly among elementary school students. Several local surveys have reported higher infestation rates among female children compared to males. Contributing factors include longer hair length, which provides more surface area for egg attachment and concealment, as well as social behaviors such as close-contact play and sharing of personal grooming items. Socioeconomic factors, including overcrowded households, limited access to healthcare products, and insufficient parental awareness, also play significant roles. In many communities, routine screening programs are inconsistent, and infestations may persist undetected for extended periods. Cultural attitudes and embarrassment surrounding lice may discourage reporting, further complicating control efforts.

Clinically, pediculosis capitis can present in a spectrum ranging from asymptomatic carriage to severe irritation and secondary complications. The hallmark symptom is pruritus, which results from a hypersensitivity reaction to lice saliva. Notably, itching does not always occur immediately after infestation. Sensitization may take several weeks to develop, meaning newly infested individuals can unknowingly transmit lice to others. In mild cases, the only visible sign may be the presence of nits attached near the scalp. In heavier infestations, scratching can lead to excoriations, scalp erythema, papules, crust formation, and secondary bacterial infections. Regional lymphadenopathy, particularly in the occipital and cervical nodes, may occur due to inflammatory responses. Although rare, chronic and severe infestations have been associated with iron-deficiency anemia due to repeated blood feeding.

Beyond the physical manifestations, the psychosocial impact of head lice infestation is substantial. Children with lice may experience teasing, bullying, and social exclusion. Schools may implement exclusion policies, requiring affected students to remain at home until treated, which disrupts academic progress and imposes additional burdens on families. Parents often report stress, frustration, and financial strain associated with repeated treatment attempts. The stigma attached to lice infestation can lead to secrecy, preventing open communication and coordinated management within communities. These broader consequences demonstrate that pediculosis capitis is not merely a minor dermatological inconvenience but a condition with educational, emotional, and social ramifications.

Conventional management strategies rely heavily on chemical pediculicides. Commonly used agents include permethrin, pyrethrins, malathion, benzyl alcohol, ivermectin, and spinosad. Permethrin, a synthetic pyrethroid, has long been considered a first-line treatment due to its relative safety profile and over-the-counter availability. It functions by disrupting sodium channels in the nervous system of lice, leading to paralysis and death. However, decades of widespread and sometimes improper use have contributed to the emergence of

resistant lice populations. Genetic mutations known as knockdown resistance (kdr) mutations alter sodium channel structure, reducing susceptibility to pyrethroids. As resistance spreads, treatment failures become more common, necessitating repeated applications or alternative therapies.

The development of resistance is not the only limitation associated with chemical treatments. Some individuals experience adverse effects such as scalp irritation, burning sensations, redness, or allergic reactions. Although severe systemic toxicity is rare, concerns persist regarding repeated exposure, particularly in young children. Additionally, the cost of commercial pediculicides may be prohibitive for families in low-resource settings, especially when multiple household members require treatment. Incomplete adherence to treatment protocols, failure to repeat applications at recommended intervals, and inadequate environmental control measures further contribute to reinfestation cycles.

In response to these challenges, increasing attention has been directed toward plant-derived essential oils as potential natural alternatives. Essential oils are concentrated volatile extracts obtained from aromatic plants through methods such as steam distillation, cold pressing, or solvent extraction. They consist of complex mixtures of bioactive compounds, including terpenes, terpenoids, phenolics, aldehydes, and alcohols. These compounds often possess insecticidal, antimicrobial, antifungal, and anti-inflammatory properties. Because essential oils contain multiple active constituents, they may exert their effects through diverse mechanisms, potentially reducing the likelihood of resistance development compared to single-compound synthetic agents.

Several essential oils have demonstrated varying degrees of pediculicidal and ovicidal activity in laboratory and clinical studies. Tea tree oil, neem oil, lavender oil, anise oil, and clove oil are among those investigated. Mechanisms of action may include disruption of the insect nervous system, inhibition of acetylcholinesterase, interference with respiratory spiracles leading to suffocation, and damage to the exoskeleton. While some commercial products incorporate combinations of essential oils, standardization of concentration, formulation, and exposure time remains inconsistent across studies, making direct comparisons challenging.

Among the candidate plants, *Eucalyptus globulus* Labill., commonly known as the blue gum tree, has attracted scientific interest. Native to Australia but widely cultivated in tropical and subtropical regions, including the Philippines, this plant is valued for its aromatic leaves and medicinal properties. The essential oil extracted from its leaves is rich in 1,8-cineole (also known as eucalyptol), along with α -pinene, limonene, and other monoterpenes. These constituents have demonstrated insecticidal, antimicrobial, anti-inflammatory, and expectorant effects in various applications. In insects, 1,8-cineole is believed to interfere with neurotransmission and respiratory function, leading to rapid immobilization and

mortality.

The potential advantages of *Eucalyptus globulus* Labill essential oil as a pediculicidal agent are multifaceted. First, its natural origin may reduce concerns regarding synthetic chemical residues and environmental persistence. Essential oils are generally biodegradable and decompose more rapidly than many conventional pesticides. Second, the plant is widely available in many regions, which may facilitate local production and reduce dependence on imported pharmaceutical products. Third, the presence of multiple bioactive compounds may provide synergistic effects, targeting different physiological pathways within lice and decreasing the probability of resistance development. Finally, cultural acceptance of herbal remedies in many communities may enhance compliance and community engagement in treatment programs.

Despite these promising attributes, gaps in knowledge remain. Variability in extraction methods, plant chemotypes, storage conditions, and formulation can influence essential oil composition and potency. Laboratory conditions do not always replicate real-world application scenarios, and safety assessments must consider appropriate dilution and potential skin sensitivity. Rigorous, controlled experimental studies are therefore necessary to establish standardized protocols, optimal concentrations, and reliable efficacy data.

This study was designed to evaluate the pediculicidal efficacy of *Eucalyptus globulus* Labill essential oil using a controlled in vitro experimental approach. By comparing different volumes of the essential oil with permethrin as a positive control and distilled water as a negative control, the research aims to generate quantitative data on mortality rates and exposure time. Through systematic observation and analysis, the study seeks to determine whether eucalyptus essential oil can serve as a viable alternative or complementary therapy in head lice management.

Addressing pediculosis capitis requires an integrated approach that combines effective treatment, preventive education, and community participation. The exploration of plant-based interventions aligns with global trends toward sustainable and environmentally responsible healthcare solutions. If proven effective and safe, eucalyptus essential oil could contribute to diversified treatment options, particularly in resource-limited settings where conventional pediculicides are inaccessible or ineffective due to resistance.

In summary, head lice infestation remains a pervasive public health challenge with biological, clinical, psychosocial, and economic dimensions. Limitations associated with conventional chemical treatments, including resistance, adverse reactions, and financial burden, highlight the urgency of identifying alternative strategies. *Eucalyptus globulus* Labill essential oil represents a promising natural candidate with demonstrated insecticidal properties and potential

advantages in accessibility and sustainability. By providing structured and evidence-based evaluation of its pediculicidal activity, this study contributes to the growing body of knowledge supporting innovative, safe, and cost-effective solutions for the management of pediculosis capitis, particularly among vulnerable school-aged populations.

II. METHODOLOGY AND MATERIALS

This chapter provides a comprehensive overview of the research procedures, materials, and experimental approaches employed to assess the pediculicidal efficacy of *Eucalyptus globulus* Labill. leaf essential oil against *Pediculus humanus capitis*, a common ectoparasite affecting school-aged children. The methodology was carefully designed to ensure scientific rigor, reproducibility, and reliability. It includes the research design, participant selection, materials, leaf extraction and preparation, bioassay procedures, experimental protocols, data collection, and ethical considerations. Each step was informed by prior studies to ensure accuracy and relevance to the research objectives.

➤ Research Design

The study employed a mixed-methods approach, integrating both quantitative and qualitative components. The quantitative aspect consisted of a laboratory-based experimental design, allowing the measurement of mortality rates of adult lice exposed to different concentrations of *Eucalyptus globulus* essential oil. The qualitative aspect involved observational data on lice behavior, movement, and responsiveness to the essential oil. This dual approach ensured that the research captured not only measurable outcomes but also behavioral responses, providing a more holistic understanding of the pediculicidal effects. The mixed-methods approach was selected because it provides several advantages over purely quantitative designs. Firstly, it allows for cross-validation of results; observational data can support or explain trends seen in mortality rates. Secondly, it provides insights into potential behavioral modifications in lice that may indicate sub-lethal effects of the essential oil. Thirdly, integrating both data types strengthens the credibility and applicability of the findings, particularly when considering natural remedies for head lice management.

➤ Participant Selection and Sample Collection

Participants were selected based on the presence of active head lice infestation, ensuring that sufficient adult lice could be collected for experimental purposes. Seven participants were included, each providing at least thirty-five (35) live adult lice. Inclusion criteria ensured that lice were viable and representative of typical infestations encountered in human hosts. Exclusion criteria involved participants with underlying scalp conditions or recent pediculicide treatment, which could compromise lice viability or alter behavior. Lice were carefully collected using fine-toothed combs, minimizing stress or physical damage. Once collected, lice were transported in ventilated containers to maintain airflow

while preventing escape. Lice were then maintained at controlled temperature (20–24°C) and relative humidity (65–70%) prior to experimentation to ensure stability and uniform physiological conditions. This careful handling minimizes variability in response and ensures reliable results.

➤ Research Materials

The primary material was mature, fully developed leaves of *Eucalyptus globulus* Labill. These were selected due to their high essential oil content, which is concentrated in mature leaves and essential for achieving observable pediculicidal effects. Leaves that were damaged, old, or diseased were excluded to maintain consistency and chemical integrity. Laboratory equipment included Petri dishes, Whatman No. 1 filter paper, micropipettes, sterile droppers, steam distillation apparatus, and airtight storage containers. Positive and negative controls consisted of Permethrin and distilled water, respectively. These controls were necessary to validate the results and compare the natural extract's efficacy with a standard pediculicide and a non-active substance.

➤ Preparation of *Eucalyptus globulus* Labill Leaf Extract

Leaves were first washed thoroughly with distilled water to remove dust and contaminants. Subsequently, they were shade-dried for 15 days, a method chosen to preserve volatile essential oils that could degrade under direct sunlight or high temperatures. After drying, leaves were cut into smaller pieces and manually crushed to increase surface area, which enhances oil release during steam distillation. This preparation method aligns with prior studies demonstrating higher oil yields from physically processed plant material. Crushed leaves were stored in airtight containers at 4°C to maintain stability and prevent moisture absorption. Such storage conditions ensure that the chemical composition of the essential oil remains intact prior to experimentation, which is critical for reproducibility and accurate assessment of pediculicidal activity.

➤ Essential Oil Extraction via Steam Distillation

Steam distillation was employed due to its efficiency in extracting volatile oils without thermal degradation. Crushed leaves were placed in a distillation apparatus, and steam was applied at controlled temperatures to vaporize essential oils. Vapor was condensed and collected as liquid oil, then separated from water using a specialized separator. The extraction duration of 6–8 hours was selected based on pilot trials and literature, which indicated that prolonged distillation ensures maximal oil yield without significant degradation. The average yield of pure essential oil was 1.8%, consistent with prior studies on *Eucalyptus globulus* Labill. Collected oil was stored in amber glass containers at low temperatures to protect it from oxidation, light exposure, and contamination. This method ensures chemical integrity and reproducibility, critical factors in experimental pharmacological studies.

➤ *Experimental Design*

The study employed a contact bioassay, a standard method for evaluating pediculicidal activity. Adult lice were exposed to three concentrations of essential oil: low (1.0 mL), medium (1.5 mL), and high (2.0 mL). Each treatment group included an equal number of lice to ensure standardized exposure conditions. The concentration range was determined based on previous studies and preliminary trials, which indicated that these volumes provided measurable effects while remaining safe for controlled laboratory handling. Multiple time intervals were observed—3, 5, 6, 8, 11, 12, 15, and 30 minutes—followed by final confirmation at 24 hours, allowing for the assessment of both immediate and delayed mortality effects.

➤ *Bioassay Procedure*

The filter paper diffusion bioassay was chosen because it allows for uniform distribution of essential oil and ensures consistent exposure for all lice. Treated filter papers were placed in Petri dishes, and lice were gently transferred using gloved hands. No carrier oils were added to ensure that observed effects were solely due to the essential oil. Mortality was defined as the absence of movement and failure to respond to gentle prodding.

➤ *Positive and Negative Controls*

To validate experimental results, Permethrin served as a positive control due to its well-established pediculicidal properties, while distilled water served as a negative control.

Comparison with controls allowed researchers to distinguish between the natural oil's effects and potential environmental or procedural influences.

➤ *Scientific Rationale for Methodology*

Every procedural choice in this study was deliberate and evidence-based. Shade-drying preserves volatile oils, steam distillation efficiently isolates active compounds, and the contact bioassay ensures measurable and reproducible exposure. Time intervals for mortality assessment were selected to detect both rapid and delayed effects, while multiple concentrations enabled dose-response evaluation. Ethical participant selection and careful lice handling ensured compliance with ethical standards and minimized extraneous variables that could compromise validity.

➤ *Ethical Considerations*

Ethical protocols were strictly observed. Parental consent was obtained for all participants, and participation was voluntary. Participants could withdraw at any time without consequence. Confidentiality was maintained, and minimal discomfort was ensured for both participants and lice. All procedures adhered to internationally accepted ethical standards for research involving human subjects.

III. RESULTS AND DISCUSSION

➤ *Overview of Experimental Findings*

This study evaluated the pediculicidal efficacy of *Eucalyptus globulus* Labill essential oil against *Pediculus humanus capitis*. Mortality was compared across three concentrations of essential oil (2.0 mL, 1.5 mL, 1.0 mL), a positive control (permethrin at 1.0, 1.5, and 2.0 mL), and a negative control (distilled water). Mortality was monitored at multiple time intervals (3, 5, 6, 8, 11, 12, 15, and 30 minutes) with a 24-hour post-treatment confirmation. Observations included both quantitative mortality counts and qualitative assessments of lice morphology and behavior. The results demonstrate that *Eucalyptus globulus* Labill essential oil exhibits strong pediculicidal activity, with mortality rates dependent on both concentration and exposure time. The highest concentration (2.0 mL) achieved complete mortality within six minutes, the 1.5 mL dose within eight minutes, and the 1.0 mL dose within twelve minutes. Permethrin achieved 100% mortality within three minutes across all concentrations, confirming its rapid chemical action. Distilled water, as expected, had no effect on lice survival. These findings indicate that *Eucalyptus globulus* Labill essential oil is a promising natural alternative to conventional chemical pediculicides. While slower than permethrin, its reliable activity across multiple concentrations supports potential practical applications, particularly in communities concerned with chemical resistance or toxicity.

➤ *Pediculicidal Activity at Varying Concentrations High Concentration (2.0 mL)*

The 2.0 mL concentration produced the fastest pediculicidal activity among the essential oil treatments. Mortality was first observed at the three-minute mark, with three lice rendered immobile. Complete mortality occurred by six minutes. Observed behaviors included leg curling, body stiffening, darkening of the exoskeleton, and cessation of movement. The rapid effect at this concentration can be attributed to the high availability of bioactive compounds such as eucalyptol, which likely penetrated the cuticle efficiently, affecting both nervous and respiratory systems. The result indicates that higher concentrations provide a more immediate and effective approach for lice eradication, making them suitable for acute infestations or situations requiring rapid intervention.

➤ *Medium Concentration (1.5 mL)*

At 1.5 mL, mortality commenced slightly later than at the higher concentration. The first signs of lethality were observed at six minutes, with complete mortality reached by eight minutes. Lice displayed gradual immobilization, curling of the legs, stiffened bodies, and darkened exoskeletons. The delayed effect suggests that lower concentrations require slightly longer exposure for bioactive compounds to accumulate sufficiently within the lice to exert their full effect. Despite the slower action, complete eradication was still achieved within a reasonable time frame, highlighting the essential oil's potency

and concentration-dependent activity.

➤ *Low Concentration (1.0 mL)*

The 1.0 mL concentration displayed the slowest pediculicidal activity among the essential oil treatments. Mortality began at eleven minutes, with the final louse succumbing at twelve minutes. Morphological and behavioral indicators mirrored those observed in higher concentrations, with leg curling, body stiffening, and darkening of the exoskeleton. Even at this minimal concentration, complete mortality was achieved, confirming that *Eucalyptus globulus* Labill essential oil retains full pediculicidal potential with adequate exposure. This is particularly important for applications aiming to minimize the amount of active ingredient while maintaining effectiveness, potentially reducing cost and risk of irritation or allergic reactions.

➤ *Time-Point Analysis and Dose-Response Relationship*

The study highlights a clear concentration- and time-dependent response. At three minutes, only the highest concentration produced partial mortality, while the medium and low doses showed no initial lethality. By six minutes, the 2.0 mL dose had achieved complete mortality, the 1.5 mL dose was approaching full eradication, and the 1.0 mL dose showed initial signs of lethality. At twelve minutes, all essential oil concentrations had achieved 100% mortality, confirming the cumulative effect of prolonged exposure. This dose-response trend aligns with pharmacological principles and supports the concept of optimizing essential oil concentration based on practical needs. Rapid action may be preferred in acute infestations, while lower concentrations may be applied in preventive or maintenance strategies.

➤ *Comparative Analysis with Permethrin and Distilled Water*

Permethrin acted rapidly across all concentrations, achieving full mortality within three minutes. Behavioral observations included immediate paralysis, contraction of legs, stiffening of the body, and darkened exoskeletons. These results reflect permethrin's well-documented neurotoxic mechanism, which alters sodium channel function in lice, leading to rapid paralysis and death. Distilled water showed no mortality, with lice remaining fully active throughout the observation period. The absence of effect confirms that mortality in treatment groups was due to active pediculicidal agents rather than environmental conditions, handling, or other external factors. The comparison demonstrates that *Eucalyptus globulus* Labill essential oil, while slower than permethrin, is highly effective and may offer advantages in resistance management and safety. Unlike permethrin, which targets a single neurochemical pathway, essential oils act on multiple targets, reducing the likelihood of resistance development.

➤ *Morphological and Behavioral Observations*

Live lice exhibited normal leg extension, translucent bodies, visible internal structures, and active movement, indicative of vitality. In contrast, treated lice displayed leg

curling, body stiffening, darkened exoskeletons, and absence of movement. These qualitative observations complement quantitative mortality data and provide clear visual confirmation of treatment efficacy. The consistent correlation between morphological changes and mortality confirms the reliability of the assessment methodology. Observing behavioral and structural changes also allows researchers to infer the physiological mechanisms of pediculicidal activity.

➤ *Mechanisms of Action*

The pediculicidal effects of *Eucalyptus globulus* Labill essential oil are likely due to multiple bioactive compounds, predominantly eucalyptol. Essential oils act through multi-targeted mechanisms, including disruption of cell membranes, interference with neurotransmission, inhibition of enzymatic processes, and oxidative stress induction. This multi-faceted action reduces the risk of resistance and may complement or replace single-target chemical pediculicides. Concentration-dependent differences reflect the availability of bioactive molecules and their ability to penetrate the exoskeleton. Higher concentrations allow faster and more extensive disruption of physiological systems, while lower concentrations achieve mortality through cumulative effects over time.

➤ *Potential for Integrated Lice Management Strategies*

The findings from this study indicate that *Eucalyptus globulus* Labill essential oil could play a crucial role in integrated lice management programs. By combining natural pediculicides with conventional treatments or preventive hygiene measures, communities may achieve more effective and sustainable control of head lice infestations. For instance, essential oil-based formulations could be used intermittently alongside permethrin to reduce the likelihood of resistance development while minimizing chemical exposure. Additionally, educational campaigns on proper application, dosage, and safety could enhance adherence and outcomes in school-aged populations. The multi-targeted action of the oil supports its use not only as a standalone treatment but also as a complementary strategy, potentially reducing treatment failures and reinfestation rates in both household and institutional settings.

➤ *Comparison with Existing Literature*

The results align with previous studies demonstrating the insecticidal activity of essential oils. Benelli et al. (2016) and Pavela & Benelli (2016) reported that essential oils exert multi-targeted effects on insects, disrupting neuromuscular and respiratory systems. Heukelbach et al. (2008) observed high mortality in lice exposed to plant-derived oils, reinforcing the potential of botanical pediculicides. Permethrin's rapid effect is well-documented, yet field studies, including Kalari et al. (2021), report reduced efficacy due to resistance, with mortality rates ranging from 60–80%. This contrast highlights the need for alternative treatments such as essential oils, which maintain efficacy even in cases of emerging chemical resistance.

➤ *Practical Applications*

Eucalyptus globulus Labill essential oil can be incorporated into natural pediculicide formulations for public health use, particularly in schools, community health programs, and pediatric care. Its concentration-dependent activity allows for flexible dosing strategies, ensuring efficacy while minimizing exposure to higher concentrations. The essential oil's slower action may be leveraged in combination treatments, where rapid chemical pediculicides are complemented by longer-acting plant-based formulations. This approach may reduce chemical resistance, minimize environmental contamination, and provide safer options for children and sensitive populations. Furthermore, plant-based pediculicides align with increasing consumer preference for natural and eco-friendly products. They provide sustainable alternatives to chemical insecticides, which may have residual toxicity and ecological impact.

IV. LIMITATIONS OF THE STUDY

Several limitations should be considered. The study was conducted in vitro, which may not fully replicate field conditions, such as hair density, scalp oils, or environmental factors. The sample size of lice was limited, potentially affecting statistical generalizability. The study did not identify or quantify individual bioactive compounds responsible for pediculicidal activity. Future research could employ chromatographic and metabolomic techniques to characterize active constituents. Additionally, variations in essential oil composition due to plant source, extraction method, and storage conditions may influence efficacy.

➤ *Scientific Contribution and Significance*

This study demonstrates that *Eucalyptus globulus* Labill essential oil is a potent pediculicide, capable of achieving 100% mortality of *Pediculus humanus capitis* in a time- and concentration-dependent manner. Its multi-targeted mode of action reduces resistance potential and supports the development of natural, plant-based pediculicide alternatives. The findings contribute to sustainable health interventions by promoting natural and environmentally friendly alternatives to chemical insecticides. They also provide a foundation for future research into essential oil-based pediculicides, including formulation, optimization, and commercialization.

➤ *Synthesis of Findings*

In summary, *Eucalyptus globulus* Labill essential oil demonstrates reliable pediculicidal activity across multiple concentrations, with mortality confirmed both immediately and after 24 hours. Its slower onset compared to permethrin is offset by its natural origin, multi-targeted action, and potential for resistance mitigation. Behavioral and morphological observations reinforce quantitative findings, and mechanistic insights explain the observed concentration-dependent effects. The results support the essential oil's potential as a practical, effective, and sustainable alternative to conventional pediculicides. They provide strong scientific and practical

rationale for integrating plant-based treatments into lice management strategies, particularly in areas facing resistance or chemical sensitivity concerns.

➤ *Implications for Public Health and Community Use*

The consistent pediculicidal activity of *Eucalyptus globulus* Labill essential oil highlights its potential role in public health programs aimed at controlling head lice infestations. School-based interventions could incorporate this natural treatment as a safe and eco-friendly alternative to chemical pediculicides. Its accessibility and affordability make it particularly suitable for low-income communities where conventional treatments may be limited or too costly. Moreover, educating caregivers and healthcare providers about appropriate use and dosing strategies could enhance compliance and effectiveness. The multi-targeted action of the oil also provides a strategic advantage in preventing the development of resistance, which is a growing concern with synthetic pediculicides like permethrin. Future integration of *Eucalyptus globulus* Labill essential oil into community health initiatives could offer a sustainable, plant-based approach to head lice management, benefiting both individual and public health outcomes.

V. CONCLUSIONS AND FUTURE DIRECTIONS

This study demonstrated that *Eucalyptus globulus* Labill essential oil exhibits strong pediculicidal activity against *Pediculus humanus capitis* under controlled laboratory conditions. Head lice infestations remain a significant public health concern, particularly in school-aged children from low-income communities where access to conventional treatments may be limited. The rising resistance of lice to chemical pediculicides, such as permethrin, highlights the urgent need for safe, effective, and affordable alternatives.

The results indicate a clear dose-dependent effect: higher concentrations of the oil achieved faster mortality, with the 2.0 mL concentration causing complete lice death in just six minutes. Lower doses, including 1.5 mL and 1.0 mL, also resulted in full mortality over longer periods, confirming the consistent efficacy of the oil across different concentrations. While the pediculicidal action of eucalyptus oil is slightly slower than permethrin, it still achieved 100% mortality within 12 minutes at the lowest dose, with effects sustained after 24 hours. The activity is attributed to bioactive compounds, particularly eucalyptol, which likely disrupt lice respiratory and nervous systems, leading to reduced mobility, discoloration, and exoskeletal damage.

In addition to its effectiveness, *Eucalyptus globulus* Labill essential oil offers safety, eco-friendliness, and affordability, making it a practical alternative to chemical pediculicides that may cause irritation, allergic reactions, or environmental harm. These findings support the oil's potential as a natural, accessible option for integrated head lice management, complementing conventional treatments and

helping to address issues of chemical resistance.

Future research should focus on field-based evaluations to determine the real-world effectiveness of eucalyptus oil under variable environmental and social conditions. Studies should explore different concentrations, formulations, and delivery methods—such as carrier oils, creams, or sprays—to optimize therapeutic efficacy while minimizing dermal irritation. Comparative studies with conventional pediculicides will help establish clinical relevance and support its use as a natural alternative. Investigating the ovicidal properties of the oil is also critical to ensure complete control of all lice developmental stages, including nits, to prevent reinfestation.

Further studies should assess the oil's effectiveness against chemically resistant lice populations, including molecular investigations into potential resistance mechanisms. Long-term research is recommended to evaluate safety with repeated use, potential allergic reactions, and reinfestation rates, which are essential for sustainable treatment strategies. Public health initiatives can promote eucalyptus oil as a plant-based, non-chemical pediculicide, emphasizing its safety, eco-friendliness, and accessibility. Collaboration among microbiologists, pharmacologists, product developers, and public health practitioners can facilitate the development of effective, safe, and accessible formulations. Additionally, exploring other potential benefits, such as antimicrobial or repellent properties, may expand its applications.

Overall, these findings and recommendations support the integration of *Eucalyptus globulus* Labill essential oil into sustainable head lice management strategies, providing communities with a reliable, safe, and environmentally friendly alternative to conventional chemical treatments.

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