Optimization and *in vitro* Characterization of Piperine-lemongrass Loaded Nanoemulsions Green Larvicide for *Aedes aegypti*

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Abstract

Aim: *Aedes aegypti* is a major vector for dengue and Zika. Rising resistance to synthetic pesticides has shifted focus toward botanical larvicides like piperine and lemongrass oil. However, these actives suffer from high hydrophobicity and environmental instability. This study aimed to develop stable, green nanoemulsions to enhance their delivery and larvicidal efficacy. **Material and Methods:** Active ingredients included piperine and lemongrass oil . The oil phase utilized olive oil, while Tween 80 and propylene glycol served as surfactant and co-surfactant. Distilled water formed the aqueous phase, with ethanol and methanol (S.D. Fine chemicals) used as analytical reagents. Triethanolamine and citric acid were employed for pH adjustment. Nine formulations (F1–F9) were designed using a 32 factorial model and prepared via low-energy emulsification followed by ultrasonication (650W, 20 kHz). Characterization was performed using Dynamic Light Scattering (DLS), Transmission Electron Microscopy (TEM), and UV-Vis spectrophotometry .**Results and Discussion:** Formulation F9 was identified as the lead system, containing 3.0% piperine and 3.0% lemongrass oil. It exhibited an optimal droplet size of 28.1±1.1 nm, a PDI of 0.165, and a zeta potential of −34.8±5.0 mV, indicating high colloidal stability. F9 demonstrated superior larvicidal potency with an LC50 of 28.5 µg/mL and 89% mortality after 48 hours. The nano-sized droplets improved penetration and contact with the larval cuticle, leading to physiological disruption and gut paralysis. **Conclusion:** The study successfully optimized a dual-active nanoemulsion that provides a 2- to 4-fold increase in efficacy over free botanical extracts. These green nanoemulsions represent a sustainable, biodegradable, and highly effective alternative for integrated mosquito management.

Key words: *Aedes aegypti*, Larvicidal activity, nanoemulsion, Lemon grass oil, piperine, biodegradable, mortality.