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Research Paper

Development of a Multi-Plant Herbal Insect Vaporizer Liquid Using Ethanolic Extracts of Medicinal Plants

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Abstract-

The widespread use of synthetic mosquito vaporizers containing pyrethroid-based compounds has raised concerns about environmental persistence, human toxicity, and the development of resistance in mosquito populations. This study reports the formulation and preliminary evaluation of an herbal insect vaporizer liquid using ethanolic extracts of *Azadirachta indica*, *Citrus limon*, and *Cymbopogon citratus*, along with the essential oil of *Eucalyptus globulus*. Plant materials were oven-dried (60°C, 48 h), powdered, and extracted with 70% ethanol by leaching for 48 h. The filtrate was stabilized with glycerin and filled into reusable vaporizer bottles. UV-Visible spectroscopic analysis revealed characteristic absorption bands in the 300–700 nm range, confirming the presence of flavonoids, terpenoids, phenolics, and chlorophyll derivatives. Preliminary qualitative assays indicated repellent activity against mosquitoes. The formulated herbal vaporizer shows promise as a biodegradable, low-cost, and eco-friendly alternative to synthetic chemical vaporizers. Further quantitative bioassays and compound profiling are recommended to standardize the product.

Keywords: Botanical repellent, Herbal vaporizer, Neem, Lemongrass, UV-Vis spectroscopy, Eco-friendly pest control.

Introduction-

Mosquito-borne diseases such as dengue, malaria, and chikungunya continue to pose major public health challenges worldwide. Household mosquito vaporizers commonly contain synthetic pyrethroids such as transfluthrin and allethrin. Although effective, prolonged exposure may result in respiratory irritation, neurotoxicity, environmental accumulation, and insecticide resistance.

Botanical insect repellents provide a promising alternative due to their biodegradability and complex phytochemical composition. Medicinal plants such as neem (*Azadirachta indica*) contain limonoids, such as azadirachtin, with insect growth-regulatory activity. Lemon (*Citrus limon*) is rich in limonene and citral with larvicidal properties.

Lemongrass (*Cymbopogon citratus*) contains geraniol and citronellal, known for spatial repellency, while eucalyptus (*Eucalyptus globulus*) oil is dominated by 1,8-cineole, a volatile fumigant compound.

The present study aims to develop a multi-plant synergistic herbal vaporizer liquid and evaluate its phytochemical presence and preliminary repellent potential.

Material and Methods-

Collection and Authentication of Plant Materials

Fresh, mature, and disease-free leaves of *Azadirachta indica* (Neem), *Citrus limon* (Lemon), and *Cymbopogon citratus* (Lemongrass) were collected from local agricultural fields in Maharashtra, India, in the early morning to minimize volatile loss. Plant materials were identified and authenticated using standard floristic keys based on morphological characteristics. Commercially available essential oil of *Eucalyptus globulus* (Nilgiri oil) was procured from a certified herbal supplier. The oil was stored in amber-colored glass bottles at room temperature until further use to prevent photo-oxidative degradation.

Preparation of Plant Material

Collected leaves were washed thoroughly under running tap water to remove adhering dust and debris, then rinsed with distilled water. Surface moisture was removed using sterile blotting paper. The cleaned leaves were oven-dried at 60°C for 48 hours to reduce moisture content and prevent microbial contamination. Controlled temperature drying was performed to preserve thermolabile phytoconstituents while ensuring complete dehydration.

Dried samples were ground in a laboratory grinder to a fine powder. The powder was passed through a 60-mesh sieve to ensure uniform particle size, which enhances extraction efficiency. The powdered samples were stored in airtight containers at room temperature until extraction.



Oven dry 60 degrees for 48 hrs



Powder form of Sample

Preparation of Ethanolic Extract

Extraction was performed using 70% (v/v) ethanol as solvent, selected for its ability to extract both polar and moderately non-polar phytochemicals. Approximately equal quantities of powdered neem, lemon, and lemongrass leaves were weighed and transferred into sterile glass conical flasks. The plant powder was immersed in 70% ethanol at a plant material-to-solvent ratio of approximately 1:10 (w/v).

The mixture was subjected to maceration (leaching) for 48 hours at room temperature, with intermittent shaking every 6–8 hours to enhance solvent penetration and metabolite diffusion. After 48 hours, the extract was filtered first through double-layered muslin cloth to remove coarse plant debris, then through Whatman No. 1 filter paper to obtain a clear filtrate. The filtrates from individual plant extracts were pooled and thoroughly mixed. A measured amount of eucalyptus essential oil was then added to the combined extract under continuous stirring to ensure uniform distribution.



Leaching of Plant Metabolites



Refilling of mosquito repellent vapourizer bottle

Formulation of Herbal Vaporizer Liquid

To enhance stability and prevent rapid phase separation, 2 mL of glycerin was added to the prepared extract mixture as a stabilizing and emulsifying agent. The mixture was stirred continuously using a magnetic stirrer for 20–30 minutes to ensure homogeneity. The final formulation was transferred into cleaned and dried empty electric mosquito vaporizer refill bottles using a sterile funnel. Bottles were sealed properly and labeled for further evaluation.

UV–Visible Spectroscopic Analysis

Preliminary phytochemical confirmation was performed using UV–Visible spectroscopy. A small aliquot of the herbal formulation was diluted with ethanol to fall within the detectable absorbance range. The absorbance spectrum was recorded from 300 nm to 700 nm using a UV–Visible spectrophotometer, with ethanol as the blank. Characteristic absorption peaks were identified and assigned based on the spectral signatures of flavonoids, terpenoids, phenolic compounds, and chlorophyll derivatives.

Preliminary Mosquito Repellent Evaluation

A preliminary qualitative repellency assessment was conducted under controlled indoor conditions. The herbal vaporizer refill was connected to a standard electric vaporizer device and operated in a closed room. Mosquito behavior was observed for signs of avoidance, reduced landing frequency, and visible knockdown, compared with a control room without vaporizer exposure. Observations were recorded at regular intervals to assess immediate and short-term repellency responses.

Results and Discussion:

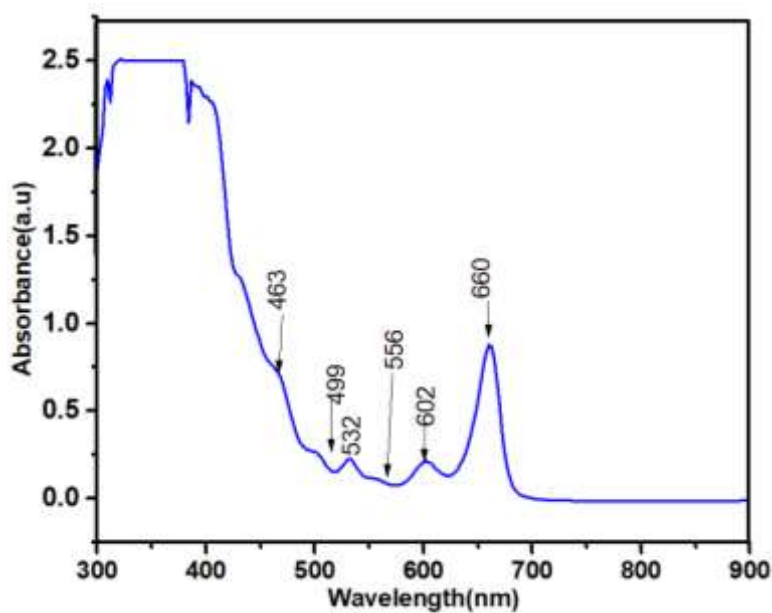
Physical Characteristics and Formulation Stability

The herbal insect vaporizer liquid was successfully formulated from ethanolic extracts of neem, lemon, lemongrass, and eucalyptus oil. The final solution was a light green to pale yellow homogeneous liquid with a characteristic aromatic odor attributable to volatile terpenoids. Immediately after preparation, the formulation exhibited uniform consistency with no visible phase separation. The addition of 2 ml of glycerin significantly improved miscibility between the ethanolic extract and eucalyptus oil, resulting in enhanced homogeneity. No precipitation or sediment formation was observed during short-term room-temperature storage.

Visual stability observations during the preliminary storage period showed: no noticeable color degradation, no turbidity, no separation of the oil layer, and retention of the characteristic fragrance. These observations suggest that glycerin served as an effective stabilizing and emulsifying agent in the formulation.

UV–Visible Spectroscopic Analysis

The UV–Visible spectroscopic profile of the herbal formulation showed multiple distinct absorption bands in both the ultraviolet and visible regions (300–700 nm), indicating the presence of diverse bioactive phytochemicals.



UV-Visible Spectroscopy

UV Region (300–400 nm)-

A strong absorption band was observed in the 300–400 nm range. This region is typically associated with: Phenolic compounds, Flavonoids, Terpenoids, Alkaloid derivatives. The presence of this band confirms the successful extraction of secondary metabolites from

neem, lemon, and lemongrass leaves. These compounds are widely documented for insect-repellent and insecticidal activity.

Visible Region (400–700 nm)-

Several characteristic peaks were detected in the visible spectrum: 463 nm - Corresponding to flavonoids and carotenoids present in citrus and lemongrass extracts. 499–532 nm – Indicative of chlorophyll derivatives and polyphenolic compounds from leaf tissues. 556 nm – Possibly attributed to metal–porphyrin complexes or chlorophyll breakdown intermediates. 602 nm – Associated with porphyrin structures and chlorophyll-a derivatives. 660 nm (major peak) – A strong absorption band characteristic of chlorophyll-a in the red region. The prominent peak at 660 nm indicates that chlorophyll pigments remained present in the ethanolic extract after drying and extraction. While chlorophyll itself is not a primary insecticidal compound, its presence indicates efficient extraction of leaf phytoconstituents and may indirectly contribute to photodynamic bioactivity. The spectral profile indicates the presence of a complex phytochemical mixture comprising limonoids, monoterpenes, flavonoids, phenolics, and porphyrin derivatives.

Evidence of Multi-Phytochemical Composition

The formulation integrates several biologically active chemical classes: Limonoids (e.g., azadirachtin) from neem, Monoterpenes (limonene, citral, geraniol, citronellal) from lemon and lemongrass, Cineole (1,8-eucalyptol) from eucalyptus oil, Polyphenols and flavonoids from leaf extracts. The simultaneous detection of UV and visible region peaks confirms that both volatile and non-volatile secondary metabolites were retained in the formulation.

Preliminary Mosquito Repellent Activity

Qualitative exposure-based assessment indicated noticeable mosquito avoidance behavior upon activation of the herbal vaporizer in a closed indoor setting. Observational findings included- Reduced mosquito landing frequency, decreased hovering behavior, Gradual dispersion of mosquitoes from treated area, Absence of immediate knockdown toxicity, suggesting primarily repellent rather than acute toxic action. The behavioural response became noticeable within a short duration after vaporizer activation, indicating adequate volatilization of active components. The repellent effect is likely attributable to volatile monoterpenes such as citral, limonene, geraniol, citronellal, and 1,8-cineole, which interfere with mosquito olfactory receptors and host-seeking behavior.

Synergistic Observations

Although no quantitative synergy index was calculated, the multi-plant formulation demonstrated a broader sensory impact compared to typical single-oil preparations reported in the literature. The combination of limonoids (growth regulators) and volatile terpenoids (spatial repellents) may enhance both immediate avoidance and longer-term population suppression. The formulation showed effective vapor diffusion, Sustained aroma intensity, and Stable phytochemical presence. These results support the hypothesis that a multi-plant extract system may provide improved repellent performance compared to mono-herbal preparations.

Discussion-

The present investigation demonstrates the feasibility of developing a multi-plant herbal vaporizer formulation using ethanolic extracts of *Azadirachta indica*, *Citrus limon*, *Cymbopogon citratus*, and *Eucalyptus globulus*. The formulation integrates phytochemicals with complementary modes of insecticidal and repellent action, supporting a synergistic approach to mosquito control.

The UV–Visible spectral profile showed strong absorption bands between 300 and 400 nm, indicative of phenolic compounds, flavonoids, and terpenoids. These classes of phytochemicals are widely reported to contribute to insect deterrence through neurotoxic, anti-feedant, and respiratory inhibition mechanisms [1,2].

The major peak observed at 660 nm corresponds to chlorophyll a derivative, suggesting the presence of porphyrin structures. While chlorophyll itself is not directly insecticidal, chlorophyll derivatives have been associated with photodynamic insecticidal properties under light exposure [3]. Additionally, peaks in the 463–532 nm range indicate the presence of flavonoids and carotenoids, compounds known to interfere with insect sensory perception and feeding behavior [4]. Neem-derived azadirachtin is a well-established insect growth regulator that disrupts ecdysone-mediated molting and reproductive cycles in mosquitoes [5]. Salannin and meliantriol function as potent anti-feedants, reducing host-seeking behavior [6]. The inclusion of *Azadirachta indica*, therefore, provides long-term population suppression rather than only short-term repellency. Limonene and citral from *Citrus limon* and *Cymbopogon citratus* act through neurotoxic and fumigant mechanisms, disrupting octopamine receptors and respiratory pathways in insects [7]. Geraniol and citronellal have demonstrated strong spatial repellency, reducing mosquito landing and biting rates in experimental trials [8]. The high concentration of 1,8-cineole (eucalyptol) in *Eucalyptus globulus* contributes significant fumigant and vapor-phase repellent action [9]. Importantly, cineole enhances volatility, improving suitability for electric vaporizer systems.

Botanical formulations often show enhanced bioactivity when multiple plant extracts are combined. Synergistic interactions may occur through: Multi-target interference in insect neurophysiology, Increased volatility and sustained vapor release, Combined larvicidal and adult repellent effects.

Previous studies have shown that mixtures of terpenoids and limonoids exhibit higher efficacy than isolated compounds due to additive and synergistic effects [10]. The present formulation integrates limonoids (azadirachtin), monoterpenes (limonene, citral), and cineole-based fumigants, which likely contribute to the preliminary repellent activity observed.

Synthetic vaporizers commonly contain pyrethroids such as transfluthrin and allethrin. Although effective, prolonged exposure has been associated with respiratory irritation, neurotoxicity, and environmental persistence [11]. In contrast, plant-derived essential oils are biodegradable and exhibit relatively lower mammalian toxicity [12]. Moreover, repeated exposure to synthetic insecticides has led to the development of mosquito resistance worldwide [13]. Botanical repellents, due to their complex mixture of bioactive molecules, reduce the probability of resistance evolution.

The addition of glycerin as a stabilizer improved homogeneity and reduced rapid evaporation. Ethanol extraction ensures efficient solubilization of both polar and moderately nonpolar phytochemicals. However, standardization of concentration and shelf-life analysis will be essential for commercialization. Future optimization should include: GC–MS profiling for compound quantification, Controlled bioassays (WHO cage method), and Toxicity evaluation of non-target organisms.

While UV–Visible spectroscopy confirmed the presence of phytochemicals, compound-specific identification was not performed. Additionally, repellency evaluation was preliminary and lacked quantitative bioassay metrics such as percentage protection time or knockdown rate. Further research should involve standardized entomological testing and dose-response modelling to validate efficacy. The study supports the growing body of evidence advocating plant-based integrated vector management strategies.

Conclusion-

Herbal vaporizers may represent a sustainable alternative in regions where synthetic repellents are either costly or associated with adverse effects. The formulation aligns with eco-friendly pest control frameworks and contributes toward green chemistry applications in public health entomology.

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