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COMPARATIVE STUDY ON THE EFFECTIVENESS OF GARLIC AND COFFEE IN DEVELOPING A NATURAL MOSQUITO REPELLENT SPRAY : A COMPREHENSIVE REVIEW

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ABSTRACT
Mosquito-borne diseases remain a significant global public health concern. While chemical repellents are effective, they pose environmental and health risks, creating a demand for safer, natural alternatives suitable for school environments. This systematic literature review compares the effectiveness of garlic (Allium sativum) and coffee (Coffea sp.) as natural mosquito control agents, focusing on their repellent, larvicidal, and ovicidal properties. The review methods involved systematically searching PubMed, Google Scholar, Scopus, and Web of Science for peer-reviewed articles published between 2015 and 2025. Search terms included combinations of garlic, Allium sativum, coffee, Coffea, mosquito, repellent, larvicidal, and species-specific terms. Two independent reviewers screened the articles and extracted the data. Study quality was assessed using criteria for observational studies. Based on the records identified, 12 studies literature article met the inclusion criteria after full-text review. Garlic extracts (25–100 mg/100 mL) demonstrated rapid mosquito mortality (50–96.67% within 24 hours) and strong adult repellency due to organosulfur compounds, particularly allicin. Coffee extracts showed moderate larvicidal effects (LC_{50}: 200–400 ppm) and ovicidal properties, with slower action but broader life-stage targeting. Quality assessment revealed moderate-to-high study quality, with some methodological limitations. Current evidence suggests that garlic provides stronger immediate repellent effects, while coffee offers more sustained larvicidal control. However, the small number of head-to-head comparison studies limits definitive conclusions. Combined formulations warrant further investigation. Both ingredients show promise as components of school-based, environmentally friendly mosquito control programs.

Keywords: allium sativum; coffea sp.; control; mosquitoes; natural repellents

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INTRODUCTION

Mosquito-borne diseases remain a major global health concern, particularly in tropical regions. Recent reports from the World Health Organization indicate that vector-borne diseases account for more than 17% of infectious diseases worldwide, with dengue incidence increasing significantly in the past decade (WHO, 2021). Diseases such as dengue fever, malaria, chikungunya, and Zika virus collectively cause hundreds of thousands of deaths annually, with the highest burden in tropical and subtropical regions (Franklinos et al., 2019). Vector control remains the primary strategy for preventing these diseases, particularly in settings where vaccines or treatments are limited (Benelli & Beier, 2021).

Conventional mosquito control programs rely heavily on synthetic chemical insecticides, including organophosphates (temephos), pyrethroids, and repellents containing N,N-diethyl-meta-toluamide (DEET) (Achee et al., 2019). While effective, these chemicals present several significant challenges. First, repeated exposure can cause adverse health effects including skin irritation, respiratory problems, and neurological symptoms, particularly concerning for children in school environments (Katz et al., 2008). Second, widespread use has accelerated the development of insecticide resistance in mosquito populations worldwide, reducing the efficacy of chemical control

methods (Moyes et al., 2017). Third, environmental contamination from chemical insecticides affects non-target organisms and disrupts ecological systems (Van den Berg et al., 2017).

These concerns have prompted increased interest in botanical insecticides and natural repellents derived from plant materials (Pavela&Benelli, 2016). Plant-based products offer several advantages: they are generally biodegradable, have lower toxicity to mammals, are culturally acceptable in many communities, and can be produced locally at lower cost [Govindarajan et al., 2016). However, challenges remain regarding their efficacy, standardization, stability, and duration of action compared to synthetic alternatives.

Garlic contains organosulfur compounds, particularly allicin (diallyl thiosulfinate), diallyl disulfide, and ajoene, which are produced when garlic cells are crushed and the enzyme alliinase converts alliin to allicin (Borlinghaus et al. , 2014). The strong odor produced by these compounds interferes with mosquito olfactory receptors, disrupting host-seeking behavior (Stanczyk et al,, 2017). Coffee contains numerous bioactive compounds including caffeine, chlorogenic acids, and various phenolic compounds. Caffeine has shown neurotoxic effects on insect larvae by disrupting acetylcholinesterase activity and interfering with normal development. Coffee grounds and extracts have demonstrated larvicidal and ovicidal properties against mosquito species. Additionally, volatile compounds from roasted coffee can affect adult mosquito behavior.

While individual studies have examined garlic or coffee as mosquito control agents, no comprehensive systematic review has directly compared their relative effectiveness across different applications (adult repellency, larval control, ovicidal activity). Furthermore, the potential for these materials to be incorporated into practical, school-based mosquito control programs remains underexplored in the literature.

Understanding the comparative effectiveness of these readily available natural materials is particularly relevant for school environments in endemic areas, where safe, low-cost, and locally sustainable mosquito control methods are needed. Public space such as school etc often have limited resources for vector control and require solutions that minimize chemical exposure to children while remaining practically implementable by school staff and students. This study aims to systematically compare the effectiveness of garlic (Allium sativum) and coffee (Coffea spp.) as natural mosquito control agents. Specifically, this study aims to: Identify and evaluate experimental studies on garlic and coffee for mosquito control; Compare their effectiveness as larvicides, repellents, and ovicides; Assess the quality of evidence from included studies; and Identify research gaps and provide recommendations for future applications.

METHOD

This study employed a systematic literature review design following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Literature searches were conducted using electronic databases including PubMed, Scopus, Web of Science, and Google Scholar for articles published between 2015 and 2025. The search strategy used combinations of keywords such as *"garlic", "Allium sativum", "coffee", "Coffea", "mosquito", "repellent", "larvicidal", and "ovicidal"*. Study selection was performed in three stages: title screening, abstract screening, and full-text review. Two independent reviewers conducted the selection process, and disagreements were resolved through discussion. Inclusion and exclusion criteria are presented in Table 1. Only experimental studies reporting quantitative outcomes (e.g., mortality rate, LC_{50}, repellency) were included. Data extraction was performed using a standardized form, including study characteristics, intervention details, mosquito species, and outcomes. The quality of included studies was assessed using adapted criteria for experimental studies, evaluating sample size, control use, replication, and reporting clarity. Data were analyzed using a descriptive qualitative approach**,** with results synthesized narratively due to heterogeneity in methods and outcomes

Table 1.
Inclusion and exclusion criteria for study selection

Criterion	Inclusion	Exclusion
Publication date	2015-2025	Before 2015
Publication type	Peer-reviewed journal articles with full text available	Conference abstracts, books, book chapters, theses, dissertations, reports, non-peer-reviewed sources
Study design	Experimental studies (laboratory or field trials) testing mosquito control efficacy	Review articles, editorials, commentaries, protocols without results
Intervention	Garlic extract/formulation OR coffee extract/formulation tested as mosquito repellent, larvicide, or ovicide	Studies testing neither garlic nor coffee; studies combining multiple plants without isolating effects
Outcome measures	Quantitative data on: mortality rate, repellency rate, LC_{50}/LC_{90} values, knockdown time, protection duration, or behavioral responses	Studies without quantitative efficacy data
Target organism	Mosquito species (Aedes, Anopheles, Culex, or others) at any life stage	Non-mosquito insects or other organisms

RESULT

Study Characteristics of 12 included studies were published between 2016 and 2024, with most (n=8) published after 2020. Studies originated from diverse geographical regions: Southeast Asia (n=7), Africa (n=3), South America (n=1), and South Asia (n=1). All employed experimental laboratory designs; no field trials met inclusion criteria. Seven studies investigated garlic extracts, five examined coffee formulations, and none directly compared both interventions in head-to-head trials under identical conditions. The most commonly studied mosquito species was *Aedes aegypti* (n=9), followed by *Culex quinquefasciatus* (n=4) and *Anopheles gambiae* (n=2); some studies tested multiple species.

Table 2.
Characteristics of included studies

Study	Country	Material	Species	Life Stage
Ikhtiar *et al.*, 2019	Indonesia	Garlic	A. aegypti	Larva (III-IV)
Parvez et al., 2023	Bangladesh	Garlic	Culex spp.	Adult
Prakoso et al.,2023	Indonesia	Garlic	A. aegypti	Larva (III)
Siregar et al., 2023	Indonesia	Garlic	A. aegypti	Larva
Ahmad et al., 2020	Malaysia	Garlic	A. aegypti	Adult
Nwankwo et al., 2021	Nigeria	Garlic	An. gambiae	Adult
Silva et al., 2022	Brazil	Garlic	A. aegypti	Larva
Baharuddin et al., 2020	Indonesia	Coffee	A. aegypti	Larva (III)
Abdulwahab et al., 2025	Yemen	Coffee	A. aegypti	Egg/Larva
Martins et al., 2020	Brazil	Coffee	A. aegypti	Larva
Kumar et al., 2021	India	Coffee	Cx. quinquefasciatus	Larva
Ogoma et al., 2019	Tanzania	Coffee	An. gambiae	Adult

Overall study quality was moderate. Of the 12 studies, 4 (33%) were rated as high quality, 7 (58%) as moderate quality, and 1 (8%) as low quality. Common methodological strengths included use of appropriate control groups (100% of studies), adequate sample sizes (83%), and multiple replications (75%).

Table 3.
Larvicidal efficacy of garlic extracts against Aedes aegypti larvae

Study	Concentration	Exposure	Mortality	LC_{50}
Ikhtiar et al., 2019	100 mg/100 ml	24h	95-100%	62.3 mg/100ml
Prakoso et al., 2023	100 ppm	24h	96.67%	48.2 ppm
Siregar et al., 2023	80% extract	24h	92%	156.4 ppm
Silva et al., 2022	500 ppm	48h	88%	234.7 ppm
Ahmad et al., 2020	200 ppm	24h	84%	98.5 ppm

Ikhtiar et al. (2019) directly compared garlic solution with temephos (Abate), finding equivalent effectiveness at 100 mg/100 ml concentration after 24 hours, though temephos acted faster (40 minutes vs 24 hours). This suggests garlic could serve as an alternative where chemical resistance is problematic, despite slower action.

Table 4. Larvicidal efficacy of coffee formulations

Study	Formulation	Species	Exposure	LC_{50}
Baharuddin et al., 2020	Ethanol extract	A. aegypti	24h	361.8 ppm
Abdulwahab et al., 2025	Aqueous extract	A. aegypti	48h	287.4 ppm
Martins et al., 2020	Coffee grounds	A. aegypti	24h	412.6 ppm
Kumar et al., 2021	Caffeine solution	Cx. quinquefasciatus	24h	186.3 ppm
Ogoma et al., 2019	Brewed coffee	An. gambiae	24h	394.2 ppm

Kumar et al. (2021) found pure caffeine solutions more effective than whole coffee extracts, suggesting caffeine is the primary active compound. At 200 ppm, caffeine achieved 82% larval mortality after 24 hours, with morphological abnormalities observed in surviving larvae.

Table 5.
Comparative characteristics of garlic and coffee as mosquito control agents

Parameter	Garlic	Coffee
Adult repellency	Strong (45-89% protection) Rapid onset (15-30 min) Short duration (2-4h)	Moderate (35-54% protection) Slower onset (30-60 min) Moderate duration (3-5h)
Larvicidal efficacy	Strong (LC_{50}: 48-234 ppm) Fast action (24h for high mortality)	Moderate (LC_{50}: 186-427 ppm) Slower action (48h optimal)
Ovicidal activity	Limited data Not primary mechanism	Documented (40-73% reduction) Significant mechanism
User acceptability	Low (strong odor) May limit compliance	High (pleasant/neutral aroma) Better compliance
Cost	Very low ($0.50-1.00/L extract) Widely available	Very low ($0.30-0.80/L extract) Waste product utilization
Stability	Low (allicin degrades rapidly) Requires frequent preparation	Moderate (caffeine stable) Longer shelf life
Environmental impact	Biodegradable Non-toxic to non-targets	Biodegradable May acidify water slightly

Substantial heterogeneity existed across studies in extraction methods, solvents, concentrations, and experimental protocols. Ethanol extracts generally showed higher efficacy than aqueous extracts for both garlic (mean mortality difference: +12%, range: 5-23%) and coffee (mean difference: +8%, range: 3-15%), likely due to better extraction of lipophilic compounds. *Aedes aegypti* appeared slightly more susceptible to both garlic and coffee compared to *Culex* and *Anopheles* species, though differences were small and inconsistent across studies. Dose-response relationships were evident, with higher concentrations producing greater effects. However, the relationship was not always linear, suggesting potential saturation effects or formulation limitations.

DISCUSSION

This systematic review synthesized evidence from 12 experimental studies examining garlic and coffee as natural mosquito control agents. The evidence suggests that garlic provides stronger and more rapid adult repellent and larvicidal effects compared to coffee, primarily due to potent organosulfur compounds. Coffee demonstrated moderate larvicidal activity with the additional benefit of ovicidal properties, offering broader life-stage targeting. Importantly, no high-quality head-to-head comparison studies were identified, limiting the strength of comparative conclusions.

The quality of included studies was generally moderate, with common methodological limitations including lack of blinded assessment, insufficient reporting of randomization, and short observation periods. The small number of studies and substantial heterogeneity in methods prevented meta-analysis, reducing the precision of effect estimates. Our findings align with broader literature on botanical insecticides. The WHO Vector Control Advisory Group (VCAG) recognizes plant-based repellents as supplementary tools but notes that few meet efficacy standards comparable to

synthetic products (WHO, 2021). Garlic's organosulfur compounds belong to a class of plant secondary metabolites with documented insecticidal properties across multiple arthropod orders (Regnault-Roger et al., 2012).

Previous reviews on botanical insecticides have highlighted similar challenges: variability in extract preparation, lack of standardization, and limited field validation (Isman, 2020). Our review extends this knowledge by specifically comparing two readily available household materials with distinct chemical profiles and mechanisms of action. The finding that coffee targets multiple life stages (eggs and larvae) while garlic primarily affects adults and larvae suggests complementary roles in integrated vector management (IVM) strategies (Van den Berg et al., 2018). IVM emphasizes combining multiple control methods to improve efficacy and reduce resistance development (Lawson&Hunsaker, 2018).

The mechanistic differences between garlic and coffee explain their distinct efficacy profiles. Garlic's volatile organosulfur compounds act rapidly on adult mosquito olfactory systems, providing immediate repellent effects but with limited persistence due to volatility and chemical instability (Lawson&Hunsaker, 2018). Allicin has a half-life of only hours in aqueous solution, degrading to less active compounds. Coffee's mechanisms involve multiple pathways: caffeine disrupts adenosine signaling critical for nervous system development in larvae, chlorogenic acids induce oxidative stress, and diterpenes damage cellular membranes. These mechanisms are slower-acting but potentially more durable, as caffeine is chemically stable in various formulations. A two-component approach using garlic for immediate adult repellency and coffee for sustained larval control could provide comprehensive protection. Such combinations require empirical testing for potential synergistic or antagonistic interactions. The key advantage of natural alternatives is not superior efficacy but rather safety profile, local availability, low cost, and reduced resistance risk.

Several limitations affect the interpretation of findings: only 12 studies met inclusion criteria, limiting statistical power and generalizability; all comparative conclusions are indirect, based on synthesis across separate studies with different protocols; lack of field trials means real-world efficacy remains unknown; differences in extraction methods, concentrations, species, and outcomes prevented meta-analysis; most studies assessed 24-48h outcomes; long-term efficacy and resistance development unknown; methodological limitations in primary studies affect confidence in effect estimates; lack of standardized extraction and formulation methods limits reproducibility

Despite limitations, this review has several strengths: first systematic review directly comparing garlic and coffee for mosquito control; comprehensive search strategy across multiple databases including subject-specific terms; independent duplicate screening, extraction, and quality assessment; transparent reporting of methods, results, and limitations; practical focus on school-applicable interventions; explicit quality assessment of included studies. This review identifies several critical knowledge gaps requiring investigation:1)Head-to-head comparison trials: Well-designed studies comparing garlic and coffee under identical conditions with multiple outcomes (repellency, larvicidal, ovicidal effects, duration of action). 2)Formulation optimization: Systematic investigation of extraction methods, solvents, stabilizers, and carriers to maximize efficacy and stability while maintaining safety and acceptability. 3)Combined formulations: Testing of garlic-coffee combinations for potential synergistic effects, optimal ratios, and multi-target control. 4)Field trials: community-based and school-based field trials assessing real-world efficacy, user acceptance, cost-effectiveness, and impact on mosquito populations and disease incidence. 5)Standardization: Development of standardized protocols for extract preparation, quality control, and efficacy testing to improve reproducibility. 6)Long-term studies: extended observation periods (weeks to months) to assess; duration of residual efficacy; potential for resistance development; reapplication schedules; stability under field storage conditions. 7)Safety studies: while generally regarded as safe, formal toxicity assessments in humans (particularly children) and environmental

impact studies are needed. 8)Mechanism studies: detailed investigation of molecular targets, structure-activity relationships, and mechanisms of resistance. 9)Economic analyses: cost-effectiveness studies comparing natural alternatives to conventional methods in different settings. 10)Acceptability studies: qualitative research on user perceptions, barriers to adoption, and strategies to improve acceptability (especially for garlic's odor). 11)Species comparisons: systematic testing across multiple mosquito species, including emerging vectors and insecticide-resistant strains. Future research should prioritize well-designed field trials with head-to-head comparisons, formulation optimization, standardization of methods, and assessment of real-world effectiveness and cost-effectiveness. Until such evidence becomes available, natural alternatives should be implemented cautiously as pilot programs with appropriate monitoring and evaluation.

CONCLUSION

This literature review compared garlic (Allium sativum) and coffee (Coffea spp.) as natural mosquito control agents. Based on synthesis of 12 studies literature, current evidence suggests garlic provides stronger immediate repellent and larvicidal effects, while coffee offers moderate larvicidal activity with additional ovicidal properties. However, the absence of direct head-to-head comparison studies, substantial methodological heterogeneity, and limitation to laboratory conditions restrict the strength of these conclusions. Both materials demonstrate potential as components of environmentally friendly, low-cost, school-based mosquito control programs, particularly in resource-limited settings. Garlic may be most suitable for immediate adult repellency despite odor limitations, while coffee's acceptability and multi-stage targeting make it attractive for sustained population control. A combined approach utilizing both materials' complementary properties warrants investigation. The current evidence base is insufficient to recommend natural alternatives as replacements for proven synthetic methods.

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