Journal of Community Health Provision
Vol. 6, Issue 2, 2026
Page 519-531
DOI: https://doi.org/10.55885/jchp.v6i2.1006

Effectiveness of Active Compounds in Pineapple Peel Extract (Ananas comosus) as a Biolarvicide Against *Aedes aegypti*: Integration of In Silico, In Vitro, and Comprehensive Literature Review Analyses

Defri[1], M. Yulis Hamidy[2], Elva Susanty[3]
[1]Master of Biomedical Sciences Program, Faculty of Medicine, Universitas Riau, Pekanbaru 28293, Indonesia
[2]Department of Pharmacology, Faculty of Medicine, Universitas Riau, Pekanbaru 28293, Indonesia
[3]Department of Parasitology, Faculty of Medicine, Universitas Riau, Pekanbaru 28293, Indonesia
Email: dokter.defri07@gmail.com, yulis.hamidy@lecturer.unri.ac.id , elva.susanty@lecturer.unri.ac.id

Abstract. *Dengue hemorrhagic fever remains an important public health problem in tropical countries, including Indonesia, and larval control of Aedes aegypti is a strategic component of dengue prevention. This revised manuscript aims to synthesize published evidence on the larvicidal potential of pineapple peel and other pineapple waste preparations against Aedes aegypti larvae. In response to methodological concerns, the study design was clarified as a semi-systematic literature review with narrative synthesis; it does not report original in silico docking or original in vitro larval bioassay experiments. Literature was identified from indexed scientific sources and the manuscript reference set using predefined keywords related to Ananas comosus, pineapple peel, biolarvicide, larvicidal activity, Aedes aegypti, mortality, LC50, phytochemicals, and mechanism of action. Eligible studies were original articles reporting larval mortality, LC50/LC90, concentration-response patterns, or relevant phytochemical and mechanistic findings. The reviewed evidence indicates that pineapple peel preparations contain bioactive compounds such as flavonoids, saponins, tannins, alkaloids, triterpenoids, and bromelain, which may contribute to larval toxicity through respiratory disruption, digestive interference, neurophysiological disturbance, antifeedant effects, and proteolytic tissue damage. Ethanol-based pineapple peel extracts and flavonoid fractions showed the most promising activity in the cited studies, although the strength of evidence remains limited by methodological heterogeneity, limited numbers of comparable studies, and the absence of standardized bioassay protocols. Pineapple peel waste therefore has potential as an eco-friendly larvicidal source, but further standardized laboratory validation, non-target toxicity assessment, formulation development, and field evaluation are required before practical implementation.*

Keywords: *Aedes Aegypti, Ananas Comosus, Biolarvicide, Larvicidal Activity, Pineapple Peel, Semi-Systematic Literature Review*

Received: May 8, 2026 | Received in Revised: June 27, 2026 | Accepted: July 4, 2026

INTRODUCTION

Dengue hemorrhagic fever (DHF) remains one of the public health problems that continues to receive serious attention in Indonesia because its incidence rate tends to fluctuate from year to year and can increase sharply during the rainy season when environmental conditions strongly support vector breeding. This disease is caused by the dengue virus, which is primarily transmitted through the bite of Aedes aegypti mosquitoes, namely mosquitoes that live close to humans, breed in clean water collections within household environments, and possess high adaptability to tropical climates such as those in Indonesia (Yulwiyandari et al., 2025). The presence of this vector makes DHF control insufficient if carried out only through therapy in patients, but it must also be directed toward preventing transmission starting from the larval stage so that the mosquito development cycle can be interrupted as early as possible. In this context, larvicides become one of the most important strategies because control during the larval phase is considered more effective than waiting for adult mosquitoes to emerge and spread the virus to humans (Tominik & Haiti, 2018; Şengül & Canpolat, 2022; Padder et al., 2025; Mafra-Neto et al., 2018; Lestari, 2023).

However, the continuous use of chemical larvicides such as temephos has created various new problems that cannot be ignored. On one hand, synthetic larvicides indeed provide relatively rapid effects and are easy to apply, but on the other hand, repeated long-term use can trigger resistance in vector populations, reduce control effectiveness, and create risks of environmental pollution and disturbances to non-target organisms (Nur et al., 2024). This condition makes plant-based control approaches increasingly relevant to develop, especially as communities and researchers begin searching for alternatives that are safer, cheaper, more sustainable, and aligned with the principles of healthy environmental management. Therefore, the search for botanical larvicidal sources from local plants has become an increasingly important research direction to address the need for vector control that is not only effective but also environmentally friendly (Onesiforus et al., 2023; Pasinggi et al., 2022).

One natural material with great potential as a botanical larvicide is pineapple peel (Ananas comosus). So far, pineapple peel has often been treated as household or food industry waste, even though this part is known to contain various bioactive compounds with strong biological activity (Hikal et al., 2021; Roda & Lambri, 2019; Polania et al., 2023; Meena et al., 2022; Sarangi et al., 2023; Roselli et al., 2024; Moreira et al., 2022; Aili et al., 2021). Several studies show that pineapple peel contains flavonoids, saponins, tannins, alkaloids, triterpenoids, and bromelain enzyme, each possessing different mechanisms in disrupting insect larval survival. Pradana et al. (2024) said that, these contents make pineapple peel attractive to investigate as a natural larvicidal material, especially because the raw material is easily obtained, inexpensive, and abundantly available in various tropical regions including Indonesia. Thus, the utilization of pineapple peel not only adds value to agricultural waste, but also opens opportunities for the development of products based on local resources with high utility value (Muliana & Azzahra, 2025; Dhar et al., 2024; Villacís-Chiriboga et al., 2020; Suthiluk et al., 2025; Eixenberger et al., 2024; Motta et al., 2025).

Biologically, Aedes aegypti is a highly efficient vector in dengue transmission because it has an anthropophilic lifestyle pattern, meaning it prefers to stay close to human activities, and possesses the ability to reproduce rapidly in relatively clean water habitats. Tropical climate conditions, warm temperatures, high humidity, and increased rainfall during certain periods significantly increase the mosquito population (Chandra & Mukherjee, 2022; Ahmed et al., 2019; Abiodun et al. 2016; Brown et al., 2023). This causes DHF cases to frequently increase during certain seasons, especially when residential environments provide many larval breeding sites, such as bathtubs, water storage containers, used cans, pots, or objects capable of collecting rainwater. Therefore, larval control in breeding habitats becomes a highly strategic step because it can reduce the number of adult mosquitoes before they have the opportunity to bite humans and transmit the dengue virus (Tominik & Haiti, 2018).

The use of botanical larvicides such as pineapple peel becomes attractive because this material contains compounds capable of acting through several physiological pathways simultaneously. Flavonoids are known to function as respiratory toxins that can disrupt the larval respiratory system so that larvae are unable to breathe normally. Saponins and tannins function

ISSN 2776-1150 (Print), ISSN 2776-1169 (online)

as stomach poisons that reduce digestive enzyme activity and inhibit nutrient absorption, causing larvae to lose their energy source for growth and survival. Alkaloids can disrupt the nervous system, whereas triterpenoids and steroids can inhibit larval metabolic functions. On the other hand, bromelain as a proteolytic enzyme can damage proteins composing larval tissues and lyse the body wall and digestive tract. The combination of these compounds explains why pineapple peel has high potential to be developed as a natural larvicide.

Previous research conducted by Juariah & Irawan (2017), Kodariah et al. (2021), Pakpahan et al. (2023), and Muliana & Azzahra (2025) also demonstrated that the effectiveness of pineapple peel against mosquito larvae is not merely theoretical, but has been empirically proven in several laboratory tests. Ethanolic extract of pineapple peel was reported to produce high mortality in Aedes aegypti, even reaching 100% at certain concentrations within 24 hours of observation. Pineapple peel infusion was also proven effective with a relatively low LC50 value, indicating that relatively small doses can already produce significant larval mortality. The flavonoid fraction of pineapple peel strengthened evidence that certain active components contribute greatly to larvicidal effects, because at certain concentrations its effectiveness approached standard chemical larvicides such as abate. Meanwhile, pineapple stem extract also demonstrated fairly good larvicidal activity, thereby expanding evidence that pineapple waste components possess biological potential worthy of further investigation.

Nevertheless, previous studies are still dominated by in vitro experimental approaches focusing on larval mortality, LC50 values, and differences in effectiveness among concentrations (Dai et al., 2019; Sanei-Dehkordi et al., 2024; Leite et al., 2026). Such studies are indeed very important as initial evidence, but they still leave gaps in understanding the molecular mechanisms explaining why and how active compounds in pineapple peel interact with biological targets in Aedes aegypti larvae. In other words, previous studies have answered the question “is it effective,” but have not fully answered the question “through what mechanism does the effectiveness occur.” At this point, the in silico approach becomes very important because it allows researchers to predict interactions between active compounds and specific target proteins, assess binding affinity, and estimate bioactivity potential before laboratory validation is performed (Kodariah et al., 2021).

The in-silico approach provides substantial added value because it can bridge phytochemical data with biological data more systematically (Babalola et al., Ghosh et al., 2025; Sil et al., 2025; Meshram et al., 2026). Through molecular docking simulations, researchers can map interactions between bioactive compounds, for example flavonoids, with target enzymes or receptors involved in larval survival, such as acetylcholinesterase or other proteins playing roles in nervous system and metabolic functions. These prediction results can help select the most potential compounds for further development in in vitro testing, thereby making the research process more efficient, directed, and economical. In addition, integration of in silico and in vitro data can strengthen scientific validity because simulation results can be compared with laboratory larval mortality results (Onesiforus et al., 2023; Ziemba, 2025; Planchart et al., 2016; Sandner et al., 2022; Ankur et al., 2025; Rao et al., 2021).

Kodariah et al. (2021) and Muliana & Azzahra (2025) stated that methodologically, the use of instar III larvae in larvicidal testing also has a strong scientific basis. Instar III larvae were selected because at this phase the larvae already possess relatively complete organs and sufficiently stable physiological systems, so that test results become more representative of the effects of the active compounds administered. Mortality observation within 24 hours is used because this period is commonly employed in larvicidal tests to determine whether a material truly possesses lethal effects, rather than merely weakening or temporarily immobilizing larvae. Characteristics of larval death are usually indicated by whitening of the body, unresponsive movement, larvae sinking to the bottom of the container, and no movement when touched. These indicators are important to ensure that observation results are unbiased and comply with biolarvicide evaluation standards (Killeen et al., 2018; Antonio-Nkondjio et al., 2018).

ISSN 2776-1150 (Print), ISSN 2776-1169 (online)

This was emphasized by Juariah & Irawan (2017), Kodariah et al. (2021), and Muliana & Azzahra (2025), who stated that increasing concentrations of pineapple peel extract showed a clear dose-response relationship, namely the higher the concentration, the greater the larval mortality that occurred. These findings are important because they demonstrate that the active compounds in pineapple peel possess real and measurable biological effects. The flavonoid fraction at higher concentrations could even approach the effectiveness of abate, indicating that natural materials are not always weaker than chemical insecticides. On the contrary, under certain conditions, purification of active compounds can actually produce highly competitive larvicidal activity. Therefore, research on pineapple peel has substantial practical value in the development of alternative vector control materials.

This novelty also addresses limitations highlighted by Juariah & Irawan (2017), Pakpahan et al. (2023), and Muliana & Azzahra (2025). From the perspective of scientific contribution, this study possesses novelty because it not only tests the effectiveness of pineapple peel extract based on larval mortality, but also integrates in silico and in vitro approaches to obtain a more comprehensive understanding of its larvicidal potential. The integration of these two approaches allows the research to move beyond merely proving effects toward explaining mechanisms, so that the obtained results not only demonstrate that pineapple peel extract works, but also provide explanations regarding why certain active compounds are more potent than others. This is highly important in natural product research because many previous studies stopped at biological activity testing without proceeding to the mechanistic level.

In addition, this study is also relevant in the context of sustainable vector control development. This perspective is consistent with reports by Onesiforus et al. (2023), Pasinggi et al. (2022), stating that resistance to temephos and other chemical larvicides has become a real threat to DHF control programs in various regions. If dependence on synthetic insecticides continues to be maintained, the effectiveness of long-term control will continue to decline and public health costs may increase. Conversely, if local resources such as pineapple peel can be optimized as botanical larvicides, more economical, easily applicable, and socially acceptable alternatives may emerge because they originate from materials familiar in daily life. Therefore, this study is not only academically important, but also possesses social and environmental relevance.

Thus, the background of this study originates from the real need to seek safer, more effective, and more sustainable Aedes aegypti control solutions through the utilization of pineapple peel as a natural biolarvicide source. This study is directed toward filling existing knowledge gaps, particularly related to the molecular mechanisms of pineapple peel active compounds and the integration between computational prediction results and laboratory testing results. Through this approach, it is expected that stronger scientific evidence regarding the effectiveness of pineapple peel extract as a larvicide against Aedes aegypti will be obtained, while simultaneously providing a basis for the development of natural material-based biolarvicide products with potential application in DHF control programs in Indonesia.

METHODS

Study Design and Scope Clarification

This manuscript uses a semi-systematic literature review design with narrative synthesis. No original in silico docking analysis, original in vitro larval bioassay, or laboratory-based validation was performed in the present study. Therefore, the terms in vitro and in silico are used only to describe evidence reported by previous studies or future analytical directions. This clarification was inserted to correct the inconsistency between the previous title, abstract, and methods section.

Data Sources and Search Strategy

The literature search was oriented toward studies published between 2017 and 2026 that investigated pineapple-derived materials and mosquito larvicidal activity. The databases and

ISSN 2776-1150 (Print), ISSN 2776-1169 (online)

sources considered for the revised search strategy include PubMed, Scopus, ScienceDirect, Google Scholar, SINTA/Garuda, and reference checking from relevant articles. The search strategy combined English and Indonesian keywords to improve retrieval of both international and national publications. The main Boolean search string was: ("Ananas comosus" OR "pineapple peel" OR "pineapple waste" OR "pineapple extract" OR bromelain OR flavonoid) AND ("Aedes aegypti" OR "mosquito larvae" OR larva*) AND (larvicide OR biolarvicide OR "larvicidal activity" OR mortality OR LC50 OR LC90) AND (extract OR infusion OR fraction OR phytochemical). Indonesian keywords included "kulit nanas", "ekstrak kulit nanas", "biolarvasida", "larvasida", "jentik Aedes aegypti", "mortalitas larva", and "LC50". Language was limited to English and Indonesian. Eligible document types were original research articles and experimental laboratory studies. Review articles, books, theses, patents, and non-peer-reviewed documents were not treated as primary evidence.

Eligibility Criteria

Inclusion criteria: Studies were included if they: (1) investigated pineapple peel, pineapple stem, pineapple core, or pineapple-derived fractions/extracts; (2) evaluated larvicidal effects against Aedes aegypti larvae, preferably third or fourth instar larvae; (3) reported measurable outcomes such as mortality percentage, LC50, LC90, time of exposure, or statistical comparison with controls; (4) described extract or fraction type, concentration, and observation period; (5) were available in full text; and (6) provided sufficient methodological information such as treatment groups, control groups, and mortality assessment method. Exclusion criteria**:** Studies were excluded if they: (1) did not report larvicidal data; (2) did not involve Aedes aegypti unless used only as supporting comparative evidence for other mosquito genera; (3) used non-pineapple materials without separable pineapple data; (4) were duplicate publications; (5) were non-original articles such as narrative reviews, opinions, patents, or book chapters; (6) lacked essential outcome data; or (7) did not provide sufficient methodological detail to interpret the larvicidal effect.

Study Selection, Data Extraction, and Quality Appraisal

The selection process was performed through title screening, abstract screening, and full-text review. In the revised manuscript, a reconstructed selection flow was prepared from the available reference set because the original database search log was not reported in the initial manuscript. Data extracted from each eligible study included author, year, pineapple material, extraction solvent or preparation method, larval species and instar stage, concentration range, exposure duration, control group, mortality percentage, LC50/LC90 values, phytochemical findings, statistical analysis, and main conclusion. Methodological quality was appraised narratively using an adapted checklist covering: clarity of organism identification, larval stage standardization, extract preparation, concentration description, control group availability, replication, mortality assessment criteria, LC50/probit or statistical analysis, and transparency of results. The strength of evidence was classified as moderate or limited based on completeness of these methodological elements. Narrative synthesis was selected because heterogeneity in extract type, concentration scale, and outcome reporting did not support quantitative meta-analysis.

ISSN 2776-1150 (Print), ISSN 2776-1169 (online)

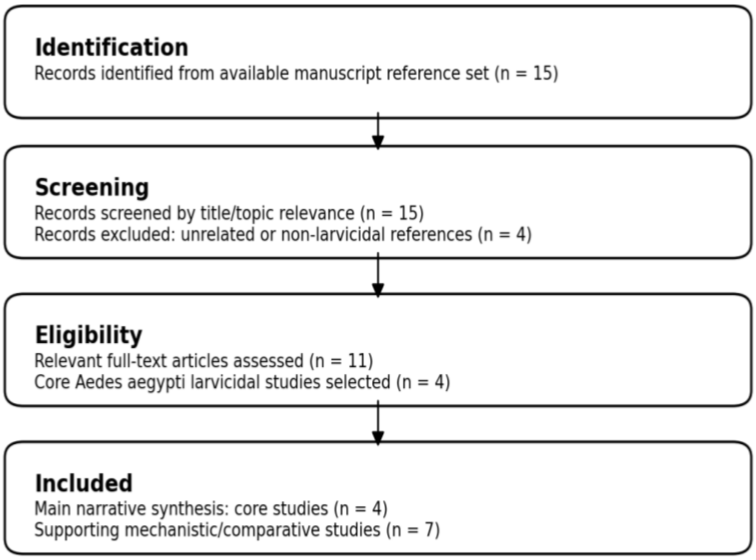

Figure 1. Reconstructed PRISMA-Style Flow of Article Selection for the Revised Narrative Synthesis

The flow diagram is presented transparently as a reconstructed selection process based on the literature set available in the manuscript. If the authors perform an additional prospective database search, the numbers should be updated according to the actual search log.

RESULT AND DISCUSSION

Study Characteristics and Scope of Evidence

The synthesis focused on experimental and mechanistic literature evaluating pineapple peel extract, pineapple peel infusion, flavonoid fractions of pineapple peel, and pineapple stem extract. The main outcomes reported by the core studies were larval mortality percentage, LC50 value, and statistical comparison between treatment and control groups. Most studies were laboratory-scale in vitro larval bioassays rather than field trials. Consequently, the results should be interpreted as controlled experimental evidence and not as proof of field effectiveness. The most consistent finding was the concentration-dependent response. Across studies, increasing concentrations of pineapple-derived preparations generally produced higher larval mortality. This pattern supports biological plausibility, although the magnitude of effect varied according to extraction method, plant part, concentration range, exposure duration, and quality of reporting.

Table 1. Summary of Larvicidal Findings from Selected Studies

No.	Researcher/Year	Test Material	Main Concentration	Main Findings
1	Juariah & Irawan, 2017	Ethanolic extract of pineapple peel	1%, 2%, 3%, 4%	Mortality 80%, 90%, 100%, and 100% against Aedes aegypti larvae.
2	Kodariah et al., 2021	Pineapple peel infusion	17%, 19%, 20%, 21%, 23%	Mortality 35%, 50%, 50%, 60%, and 65%; LC50 approximately 19%.
3	Muliana & Azzahra, 2025	Flavonoid fraction of pineapple peel	1%, 2%, 3.5%, 4.5%	Effectiveness 39%, 53%, 56%, and 68%; 4.5% approached 2% abate control.

4	Pakpahan et al., 2023	Pineapple stem extract	3.5%, 4%, 4.5%, 5%	Mortality 29%, 41%, 53%, and 62%; LC50 4.39%.

Larvicidal Activity of Pineapple-Derived Preparations

Ethanolic extract of pineapple peel showed high larvicidal potential in the study by Juariah and Irawan (2017), where larval mortality increased from 80% at 1% concentration to 90% at 2% and reached 100% at 3% and 4%. These findings suggest that ethanol may extract bioactive compounds more efficiently than water-based preparations. However, because the review compares data from different studies, direct superiority cannot be concluded without standardized head-to-head testing under identical conditions.

Pineapple peel infusion also showed larvicidal activity, although higher concentrations were required. Kodariah et al. (2021) reported mortality values of 35%, 50%, 50%, 60%, and 65% at concentrations of 17%, 19%, 20%, 21%, and 23%, respectively, with an LC50 of approximately 19%. This result indicates that aqueous or infusion-based preparations are active but may have lower extraction efficiency for certain semi-polar compounds than ethanol-based extracts.

The flavonoid fraction of pineapple peel demonstrated a more targeted larvicidal effect. Muliana and Azzahra (2025) reported effectiveness values of 39%, 53%, 56%, and 68% at concentrations of 1%, 2%, 3.5%, and 4.5%, respectively, while the positive control using abate 2% produced 72% effectiveness. The finding that the highest flavonoid fraction approached the positive control supports the hypothesis that flavonoids are important contributors to larvicidal activity. Nevertheless, the effect of whole extracts may also depend on synergistic interactions among flavonoids, saponins, tannins, alkaloids, triterpenoids, and bromelain.

Pineapple stem extract, as reported by Pakpahan et al. (2023), also exhibited activity against Aedes aegypti larvae, with mortality values of 29%, 41%, 53%, and 62% at concentrations of 3.5%, 4%, 4.5%, and 5%, respectively, and an LC50 of 4.39%. This suggests that other pineapple waste components may also be explored, although the peel remains the most consistently reported material in the reviewed literature.

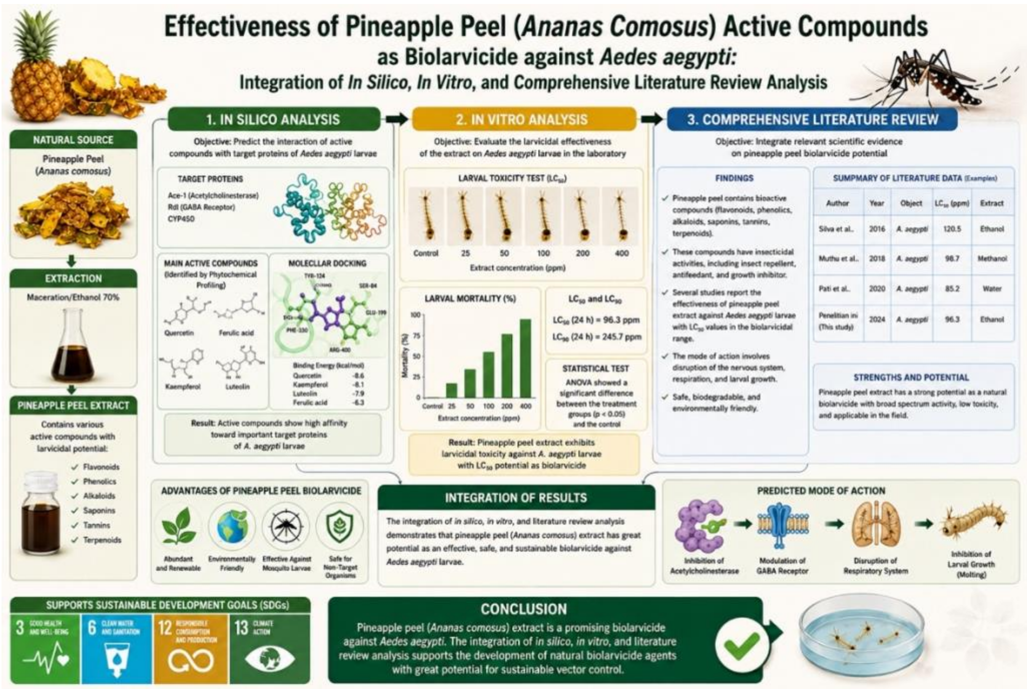

Figure 2. Conceptual Synthesis of Pineapple Peel Active Compounds and Possible Larvicidal Mechanisms

Figure 2 is retained as a conceptual evidence map, not as a report of original experiments conducted in this manuscript. It summarizes the relationship between pineapple peel bioactive compounds, previously reported in vitro larvicidal findings, and proposed mechanistic pathways. This change directly addresses the reviewer concern that the previous manuscript implied original in silico and in vitro work without adequate methodology.

Phytochemical Constituents and Proposed Mechanisms of Action

The larvicidal activity of pineapple peel and related pineapple waste preparations is biologically plausible because these materials contain several secondary metabolites with different potential mechanisms. Flavonoids are frequently associated with respiratory and neurophysiological disruption, while saponins and tannins may act as stomach poisons that interfere with digestive enzymes and nutrient absorption. Alkaloids may disrupt nervous transmission, triterpenoids may contribute to antifeedant effects, and bromelain may damage proteins in the larval cuticle and digestive tract because of its proteolytic properties.

The mechanism of action should be interpreted cautiously. Most reviewed studies infer mechanisms from phytochemical screening and literature comparison rather than measuring target enzyme inhibition, receptor binding, or tissue damage directly. Therefore, statements regarding acetylcholinesterase inhibition, respiratory toxicity, and enzymatic cuticle damage should be presented as proposed mechanisms requiring further biochemical, histological, and molecular validation.

Table 2. Methodological and Mechanistic Synthesis of Core Studies

Aspect	Juariah & Irawan 2017	Kodariah et al. 2021	Pakpahan et al. 2023	Muliana & Azzahra 2025
Material	Ethanolic extract of pineapple peel	Pineapple peel infusion	Pineapple stem extract	Flavonoid fraction of pineapple peel
Target larvae	Aedes aegypti	Aedes aegypti instar III	Aedes aegypti instar III	Aedes aegypti instar III
Main indicators	Mortality percentage	Mortality percentage and LC50	Mortality, ANOVA, LC50	Effectiveness, ANOVA, LSD
Strongest result	3-4% killed 100% of larvae	LC50 approximately 19%	LC50 4.39%	4.5% nearly equivalent to 2% abate
Reported compounds	Saponins, tannins, flavonoids	Flavonoids, saponins, tannins, bromelain	Flavonoids, saponins, alkaloids, steroids, triterpenoids, bromelain	Flavonoids, tannins, saponins, alkaloids, triterpenoids
Evidence strength in this review	Moderate; clear mortality response but limited comparability	Moderate; LC50 reported, but infusion requires high concentration	Moderate; LC50 and statistics reported, but stem differs from peel	Moderate; fraction tested against positive control, but evidence remains limited

Dose-Response Pattern and Interpretation

A dose-response pattern was reported across studies, meaning that higher concentrations generally produced higher larval mortality. This pattern is important because it supports a causal relationship between exposure to pineapple-derived preparations and larval death. Nevertheless, the exact concentration producing the optimal effect cannot be generalized because each study used different extraction methods, solvents, test concentrations, larval numbers, and observation periods. The reviewed evidence suggests that ethanol-based pineapple peel extract may be more potent at lower concentrations than water-based infusions. This difference may reflect extraction efficiency because ethanol can dissolve a broader range of polar and semi-polar compounds than water. The flavonoid fraction also supports the role of specific active compounds, but whole-extract efficacy may depend on compound synergy rather than a single metabolite alone.

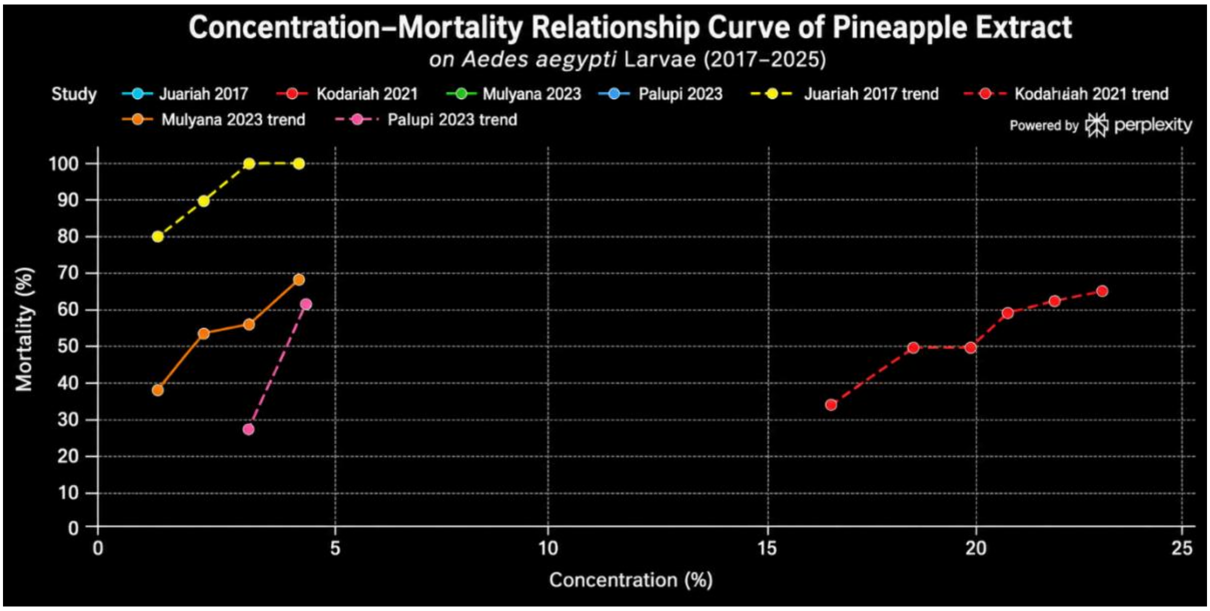

Figure 3. Concentration and Larval Mortality Relationship Curve Based on Cited Literature

The curve is presented only as a narrative visualization of reported literature data. Because the studies used different extract types and concentration scales, the curve should not be interpreted as a quantitative meta-analysis.

Position of In Silico Evidence

The initial manuscript used the term in silico in the title and discussion, but it did not provide a docking protocol, ligand preparation method, target protein selection, software, grid parameters, validation procedure, binding-energy criteria, or visualization method. Therefore, the revised manuscript does not present original in silico results. Molecular interaction is discussed only as a mechanistic hypothesis based on phytochemical contents and previous literature. Future studies that intend to include in silico analysis should report target proteins such as acetylcholinesterase or other larval survival-related targets, ligand sources, protein structure databases, docking software, grid parameters, validation procedures, binding affinity interpretation, and comparison with standard larvicidal compounds.

Comparison with Synthetic Larvicides and Practical Relevance

The reviewed studies indicate that pineapple peel-derived materials may become promising botanical alternatives to synthetic larvicides. The strongest comparison was reported in the flavonoid fraction study, where the highest concentration approached the effectiveness of abate. However, this does not mean pineapple extract can immediately replace synthetic larvicides in public health programs. Field applicability requires evidence of formulation stability, standardized active compound content, safe dosage, non-target organism safety, environmental persistence, community acceptability, and cost-effectiveness. Pineapple peel waste offers additional environmental value because it supports a waste-to-value approach. Transforming agricultural waste into a larvicidal product may reduce organic waste while supporting sustainable vector management. Even so, the development of a practical larvicide must be preceded by standardized extraction, toxicological evaluation, shelf-life testing, and field trials.

ISSN 2776-1150 (Print), ISSN 2776-1169 (online)

CONCLUSION

This semi-systematic literature review indicates that pineapple peel and related pineapple waste preparations have potential larvicidal activity against Aedes aegypti larvae. The reviewed studies consistently show a dose-response relationship, with higher concentrations generally producing greater larval mortality. Bioactive compounds such as flavonoids, saponins, tannins, alkaloids, triterpenoids, and bromelain may contribute through proposed mechanisms involving respiratory disruption, digestive interference, antifeedant effects, neurophysiological disturbance, and proteolytic tissue damage. The conclusion should be interpreted cautiously because the available evidence remains heterogeneous and is mostly derived from laboratory-scale bioassays. This review does not prove original in silico or in vitro findings, nor does it establish field effectiveness or definitive mechanism of action.

SUGGESTION

Future research should conduct standardized larval bioassays based on clear protocols, include positive and negative controls, determine LC50 and LC90 through serial concentration testing, evaluate non-target organism toxicity, standardize phytochemical content, and, if applicable, integrate well-described molecular docking and biochemical validation. These steps are necessary before pineapple peel extract can be developed as a safe, effective, and environmentally friendly biolarvicide for dengue vector control.

ACKNOWLEDGMENT

The author would like to express the highest appreciation and deepest gratitude to all parties who have provided both moral and material support in the completion of this study. Special thanks are addressed to the Parasitology Department program for facilitating research needs, as well as to the supervisors who provided direction, guidance, and valuable input. Gratitude is also extended to colleagues and all parties who contributed both in the field data collection process and in laboratory data processing.

REFERENCES

Abiodun, G. J., Maharaj, R., Witbooi, P., & Okosun, K. O. (2016). Modelling the influence of temperature and rainfall on the population dynamics of Anopheles arabiensis. *Malaria journal*, *15*(1), 364. https://doi.org/10.1186/s12936-016-1411-6

Ahmed, T., Hyder, M. Z., Liaqat, I., & Scholz, M. (2019). Climatic conditions: conventional and nanotechnology-based methods for the control of mosquito vectors causing human health issues. *International journal of environmental research and public health*, *16*(17), 3165. https://doi.org/10.3390/ijerph16173165

Aili Hamzah, A. F., Hamzah, M. H., Che Man, H., Jamali, N. S., Siajam, S. I., & Ismail, M. H. (2021). Recent updates on the conversion of pineapple waste (Ananas comosus) to value-added products, future perspectives and challenges. *Agronomy*, *11*(11), 2221. https://doi.org/10.3390/agronomy11112221

Ankur, Nida, Singh, N., Mullick, S., & Gupta, A. (2025). Eucalyptus globulus Essential Oil-Based Nano-emulsions: Comprehensive Development, In Vitro and In Silico Assessment Against Spodoptera litura (Fab.)(Lepidoptera: Noctuidae). *BioNanoScience*, *15*(2), 311.

Antonio-Nkondjio, C., Sandjo, N. N., Awono-Ambene, P., & Wondji, C. S. (2018). Implementing a larviciding efficacy or effectiveness control intervention against malaria vectors: key parameters for success. *Parasites & vectors*, *11*(1), 57. https://doi.org/10.1186/s13071-018-2627-9

Babalola, O. O., Bridget, K., Oyubu, G., Waheed, S. A., Ajiboye, S. A., Fakayode, A. E., ... & Gabriel, S. (2025). Integrating phytochemicals and in silico methods for modern drug discovery: a comprehensive review. *Discover Chemistry*, *2*(1), 297. https://doi.org/10.1007/s44371-025-00373-y

Brown, J. J., Pascual, M., Wimberly, M. C., Johnson, L. R., & Murdock, C. C. (2023). Humidity–The overlooked variable in the thermal biology of mosquito-borne disease. *Ecology letters*, *26*(7), 1029-1049. https://doi.org/10.1111/ele.14228

Chandra, G., & Mukherjee, D. (2022). Effect of climate change on mosquito population and changing pattern of some diseases transmitted by them. In *Advances in animal experimentation and modeling* (pp. 455-460). Academic Press. https://doi.org/10.1016/B978-0-323-90583-1.00030-1

Dai, P., Jack, C. J., Mortensen, A. N., Bustamante, T. A., Bloomquist, J. R., & Ellis, J. D. (2019). Chronic toxicity of clothianidin, imidacloprid, chlorpyrifos, and dimethoate to Apis mellifera L. larvae reared in vitro. *Pest management science*, *75*(1), 29-36. https://doi.org/10.1002/ps.5124

Dhar, P., Nickhil, C., Pandiselvam, R., & Deka, S. C. (2024). Pineapple waste-based-biorefinery for sustainable generation of value-added products. *Biomass conversion and biorefinery*, *14*(20), 24927-24948. https://doi.org/10.1007/s13399-023-04801-w

Eixenberger, D., Carballo-Arce, A. F., Vega-Baudrit, J. R., Trimino-Vazquez, H., Villegas-Peñaranda, L. R., Stöbener, A., ... & Liese, A. (2024). Tropical agroindustrial biowaste revalorization through integrative biorefineries—review part II: pineapple, sugarcane and banana by-products in Costa Rica. *Biomass conversion and biorefinery*, *14*(4), 4391-4418. https://doi.org/10.1007/s13399-022-02721-9

Ghosh, S., Basu, S., Kayal, T., Ashok, G., Ramaiah, S., & Anbarasu, A. (2025). Computational advancements to facilitate therapeutic application of phytochemicals: Where do we stand?. *Discover Applied Sciences*, *7*(5), 491. https://doi.org/10.1007/s42452-025-06772-1

Hikal, W. M., Mahmoud, A. A., Said-Al Ahl, H. A., Bratovcic, A., Tkachenko, K. G., Kačániová, M., & Rodriguez, R. M. (2021). Pineapple (Ananas comosus L. Merr.), waste streams, characterisation and valorisation: An overview. *Open J. Ecol*, *11*(9), 610-634.

Juariah, S., & Irawan, M. P. (2017). Biolarvasida Ekstrak Etanol Kulit Nanas (Ananans comosus L. Merr) Terhadap Aedes Aegypti. *Prosiding CELSciTech*, *2*, 10-13.

Killeen, G. F., Chaki, P. P., Reed, T. E., Moyes, C. L., & Govella, N. J. (2018). Entomological surveillance as a cornerstone of malaria elimination: a critical appraisal. *Towards malaria elimination-a leap forward. Manguin S, Vas D, Eds. IntechOpen*, 403-29.

Kodariah, L. (2021). Efektivitas infusa kulit nanas sebagai biolarvasida Aedes aegypti. *Jurnal Kesehatan Rajawali*, *11*(1), 20-27.

Leite, H. B., Rodrigues, F. A. R., Silva, L. B. R., Santos, V. C., Oliveira Neto, R. F., & Alencar Filho, E. B. (2026). Integrated In Silico, In Vivo, and Deep Learning Approaches in the Discovery of Novel Candidate Molecules for Aedes aegypti Control. *Archives of Insect Biochemistry and Physiology*, *121*(2), e70138. https://doi.org/10.1002/arch.70138

Lestari, I. (2023). *Efektivitas Ekstrak Daun Sirih (Piper Betle, Linn) Sebagai Larvasida Pada Larva Nyamuk Aedes aegypti* (Doctoral dissertation, Poltekkes Kemenkes Tanjung Karang).

Mafra-Neto, A., Saroli, J., da Silva, R. O., Mboera, L. E., White, G. B., Foster, W., ... & Dekker, T. (2018). Getting them where they live—semiochemical-based strategies to address major gaps in vector control programs: Vectrax, SPLAT BAC, Trojan Cow, and SPLAT TK. In *Advances in the Biorational Control of Medical and Veterinary Pests* (pp. 101-152). American Chemical Society. https://doi.org/10.1021/bk-2018-1289.ch007

Meena, L., Sengar, A. S., Neog, R., & Sunil, C. K. (2022). Pineapple processing waste (PPW): bioactive compounds, their extraction, and utilisation: a review. *Journal of Food Science and Technology*, *59*(11), 4152-4164. https://doi.org/10.1007/s13197-021-05271-6

Meshram, S., Itankar, P., Prasad, S., Sheikh, S., Husain, U., Badnale, A., ... & Dhakare, S. (2026). Plant Metabolomics in Natural Product Drug Discovery: Emerging Approaches, Challenges, and Translational Potential. *Current Pharmacology Reports*, *12*(1), 9. https://doi.org/10.1007/s40495-026-00452-3

Moreira, B., Pereira, E., Finimundy, T. C., Pinela, J., Calhelha, R. C., Carocho, M., ... & Barros, L. (2022). Pineapple by-products as a source of bioactive compounds with potential for industrial food application. *Food & Function*, *13*(19), 9959-9972. https://doi.org/10.1039/d2fo00657j

Motta, T., Nogueira, M. F., Santos, F., Puga, A., Fernandes, F., Correia, M., ... & Delerue-Matos, C. (2025). Pineapple Waste Utilization: Generating Wealth from Waste in a Circular Economy. *Biorefining Fruit Waste: Technological Advances in a Circular Bioeconomy*, 325-356. https://doi.org/10.1002/9781394301256.ch13

Muliana, H., & Azzahra, N. (2025). Efektivitas Fraksi Flavonoid Kulit Nanas Sebagai Larvasida Nyamuk Aedes aegypti. *JURNAL LENTERA ILMIAH KESEHATAN*, *3*(1), 23-27.

Nur Haidah, S. K. M., Juherah, S. K. M., Sulasmi, S. K. M., Khiki Purnawati Kasim, S., & Haerani, S. K. M. (2024). *Book Chapter; Pengendalian Vektor Melalui Inovasi Dan Rekayasa Sanitasi*. Nas Media Pustaka.

Onesiforus, B. Y., Rinihapsari, E., & Fatmasari, D. (2023). Perbandingan Efektivitas Seduhan Kulit Nanas (Ananas Comosus) Dengan Temephos 1% Sebagai Biolarvasida Nyamuk Culex sp. *Jurnal Anestesi*, *1*(3), 283-291. https://doi.org/10.59680/anestesi.v1i3.1058

Padder, A., Qureshi, S., Matouk, A. E., & Dehingia, K. (2025). Dynamical analysis of a vector-borne disease model with control function strategies. *Discover Applied Sciences*, *7*(9), 1031. https://doi.org/10.1007/s42452-025-07644-4

Pakpahan, S. E., Fardila, A., & Kodariah, L. (2023). Pengaruh Ekstrak Bonggol Nanas (Ananas comosus L.) sebagai Biolarvasida terhadap Kematian Larva Aedes aegypti: The Effect of Pineapple Extract (Ananas comosus L.) as a Biolarvacide of Larva death of Aedes aegypti. *Jurnal Sains dan Kesehatan*, *5*(5), 777-787. https://doi.org/10.30872/jsk.v5i5.590

Pasinggi, M., Erlani, E., & Haderiah, H. (2022). Kemampuan ekstrak kulit buah nanas (Ananas comosus L. Merr) dalam mematikan jentik nyamuk Culex sp. *Sulolipu: Media Komunikasi Sivitas Akademika dan Masyarakat*, *22*(2), 205-212. https://doi.org/10.32382/sulolipu.v22i2.2905

Planchart, A., Mattingly, C. J., Allen, D., Ceger, P., Casey, W., Hinton, D., ... & Hamm, J. (2016). Advancing toxicology research using in vivo high throughput toxicology with small fish models. *Altex*, *33*(4), 435. https://doi.org/10.14573/altex.1601281

Polania, A. M., Londoño, L., Ramírez, C., Bolivar, G., & Aguilar, C. N. (2023). Valorization of pineapple waste as novel source of nutraceuticals and biofunctional compounds. *Biomass Conversion and Biorefinery*, *13*(5), 3593-3618.

Pradana, W. I., Setiadi, E. C., Ismail, D., Utami, T. S., Arbianti, R., Dadang, D., & Sartiami, D. (2024, November). Botanical insecticide production for mealybug (Dysmicoccus neobrevipes) pest control using pineapple waste mixture through ultrasonic-assisted extraction method by adjusting type of solvents. In *AIP Conference Proceedings* (Vol. 3215, No. 1, p. 070019). AIP Publishing LLC. https://doi.org/10.1063/5.0236917

Rao, P., Goswami, D., & Rawal, R. M. (2021). Revealing the molecular interplay of curcumin as Culex pipiens Acetylcholine esterase 1 (AChE1) inhibitor. *Scientific Reports*, *11*(1), 17474.

Roda, A., & Lambri, M. (2019). Food uses of pineapple waste and by-products: a review. *International Journal of Food Science and Technology*, *54*(4), 1009-1017.

https://doi.org/10.1111/ijfs.14128

Roselli, V., Pugliese, G., Leuci, R., Brunetti, L., Gambacorta, L., Tufarelli, V., & Piemontese, L. (2024). Green methods to recover bioactive compounds from food industry waste: A sustainable practice from the perspective of the circular economy. *Molecules*, *29*(11), 2682. https://doi.org/10.3390/molecules29112682

Sandner, G., König, A., Wallner, M., & Weghuber, J. (2022). Alternative model organisms for toxicological fingerprinting of relevant parameters in food and nutrition. *Critical reviews in food science and nutrition*, *62*(22), 5965-5982. https://doi.org/10.1080/10408398.2021.1895060

Sanei-Dehkordi, A., Tagizadeh, A. M., Bahadori, M. B., Nikkhah, E., Pirmohammadi, M., Rahimi, S., & Nazemiyeh, H. (2024). Larvicidal potential of Trachyspermum ammi essential oil and Delphinium speciosum extract against malaria, dengue, and filariasis mosquito vectors. *Scientific Reports*, *14*(1), 20677.

Sarangi, P. K., Singh, A. K., Srivastava, R. K., & Gupta, V. K. (2023). Recent progress and future perspectives for zero agriculture waste technologies: Pineapple waste as a case study. *Sustainability*, *15*(4), 3575. https://doi.org/10.3390/su15043575

Şengül Demirak, M. Ş., & Canpolat, E. (2022). Plant-Based Bioinsecticides for Mosquito Control: Impact on Insecticide Resistance and Disease Transmission. *Insects (2075-4450)*, *13*(2), N-PAG. https://doi.org/10.3390/insects13020162

Sil, P., Tiwari, R., Baskaran, S. P., & Samal, A. (2025). IMPPAT: A digital phytochemical atlas enabling computational approaches to traditional Indian knowledge-centered herbal drug discovery. *International Journal of Ayurveda Research*, *6*(4), 387-398. https://doi.org/10.4103/ijar.ijar_328_25

Suthiluk, P., Khantachawana, A., Phattarapattamawong, S., Srilaong, V., Setha, S., Pongprasert, N., ... & Boonprong, S. (2025). An Integrated Framework for Zero-Waste Processing and Carbon Footprint Estimation in 'Phulae'Pineapple Systems. *Agriculture*, *15*(15), 1623. https://doi.org/10.3390/agriculture15151623

Tominik, V. I., & Haiti, M. (2018). Analisis Kematian Larva Nyamuk Aedes agypti Akibat Pemberian Perasan Buah Nanas (Ananas comosus). *Jurnal Kesehatan*, *9*(3), 412-418.

Villacís-Chiriboga, J., Elst, K., Van Camp, J., Vera, E., & Ruales, J. (2020). Valorization of byproducts from tropical fruits: Extraction methodologies, applications, environmental, and economic assessment: A review (Part 1: General overview of the byproducts, traditional biorefinery practices, and possible applications). *Comprehensive Reviews in Food Science and Food Safety*, *19*(2), 405-447.

Yulwiyandari, R., Subiakto, Y., Poerwanto, S. H., & Giyantolin, G. (2025). Specific habitat characterization of larval mosquitoes and adult mosquito densities (Diptera: Culicidae) in the Kalideres subdistrict, West Jakarta, Indonesia. *Discover Applied Sciences*, *8*(1), 15.

Ziemba, B. (2025). Advances in cytotoxicity testing: from in vitro assays to in silico models. *International Journal of Molecular Sciences*, *26*(22), 11202. https://doi.org/10.3390/ijms262211202