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Physical characteristics and insecticidal activity of mosquito-control candles containing Gerga citrus (*Citrus* sp.) peel powder against *Aedes aegypti*

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ABSTRACT

Gerga (*Citrus* sp.) peel is a horticultural by-product with potential as a natural active ingredient in mosquito-control candles. This study evaluated the physical characteristics of candles containing Gerga peel powder and their effectiveness in inducing mortality in *Aedes aegypti*. The study employed a completely randomized design comprising four treatments: P0 (control), P1 (1 g of Gerga peel powder), P2 (2 g), and P3 (3 g), with each treatment tested in triplicate. The candle base consisted of 5 g of paraffin and 5 g of stearic acid. The evaluated parameters included physical characteristics, melting point, burning time, hedonic acceptance, and *Aedes aegypti* mortality. For the mortality test, the mosquitoes were exposed to a burning candle for 60 min in a controlled chamber and subsequently maintained on a 10% sugar solution for 24 h. All formulations exhibited satisfactory physical characteristics. The addition of Gerga peel powder did not significantly affect the melting point or burning time but significantly increased *Aedes aegypti* mortality. P3 produced the highest mortality rate (61.67%) and obtained the highest panelist acceptance scores for all hedonic attributes. These findings indicate that candles formulated with Gerga peel powder have potential as a plant-based alternative for mosquito control.

Keywords: *Aedes aegypti; Citrus sp.; Gerga peel powder; mortality; mosquito-control candle.*

INTRODUCTION

Aedes aegypti is the principal vector of dengue fever, which remains a major public-health concern in tropical regions, including Indonesia. Vector control commonly relies on synthetic insecticides delivered as aerosols, electrical products, or mosquito coils. Although these products can suppress mosquito populations, repeated application may contribute to environmental contamination, increase household exposure to chemicals, and promote insecticide resistance in mosquito populations (Lolo & Wiyono, 2023). These concerns underscore the need for safer, environmentally responsible, and sustainable vector-control approaches based on plant-derived active compounds.

Mosquito-control candles are convenient plant-based preparations that can serve as an alternative means of mosquito control. Unlike synthetic insecticides, botanical candles gradually release naturally occurring volatile compounds during combustion, allowing these substances to act on mosquitoes in the surrounding area (Dutta et al., 2022). Their suitability, however, depends not only on biological efficacy but also on physical quality, including shape stability, surface uniformity, melting point, and burning time. Consequently, the development of botanical mosquito-control candles should address both mosquito-control activity and the physical quality required for practical community use.

Gerga peel (*Citrus* sp.) is a characteristic horticultural waste material from Bengkulu with considerable potential as a natural active ingredient, although its current utilization remains limited. Gerga is a leading commodity in Lebong Regency and may therefore be developed as a raw material for products derived from local resources (Marcellina et al., 2024). The peel contains secondary metabolites and volatile constituents, particularly limonene and other terpenoids, that exhibit biological activity against insects (Andriani & Rendowaty, 2024). Using Gerga peel in mosquito-control candles would not only provide a botanical mosquito-control product but also add value to horticultural waste by applying circular-economy principles to local-resource management (Priatna et al., 2025). This approach is consistent with the reduce, reuse, and recycle (3R) framework because it converts organic waste into a useful product while helping to reduce residual accumulation in the environment (Prakasa et al., 2025).

The use of citrus peel as an insect-control material has been widely reported, although most studies have focused on essential oils rich in volatile compounds. Juliadi et al. (2025) reported that a spray containing 15% kaffir lime (*Citrus hystrix*) essential oil provided 93.76% protection against Ae. aegypti for six hours. Other studies showed that 10% sweet-orange (*Citrus sinensis*) peel essential oil produced 86.4% insecticidal activity,

whereas an aromatherapy candle containing 12% lime (*Citrus aurantifolia*) peel essential oil provided 89.2% protection (Hermawan et al., 2021; Rusli & Rerung, 2018). Nevertheless, essential-oil isolation requires specialized equipment, is relatively time-consuming, and generally yields only a small amount of product (Tutuarima & Intara, 2020). These limitations raise production costs and reduce feasibility for household or small-scale industrial applications. Dried peel powder offers a simpler alternative because it requires only drying and milling, thereby potentially lowering the cost of producing plant-based repellent products.

The incorporation of dried Gerga peel powder (*Citrus* sp.) into mosquito-control candle formulations has rarely been reported. Previous studies have generally assessed the biological effectiveness of active ingredients without simultaneously evaluating the physical properties of the final preparation and consumer acceptance. Yet all three aspects are important when determining whether a product is suitable for further development and public use. Accordingly, this study examined the effects of adding Gerga peel powder at different concentrations on candle melting point and burning time, effectiveness against *Aedes aegypti* mortality, and panelist acceptance. The findings are expected to provide a scientific basis for developing an effective, value-added, and environmentally responsible mosquito-control candle from locally available horticultural waste.

METHODS

Research Design

The study was conducted in January 2026 at the Laboratory of the Faculty of Teacher Training and Education, Universitas Bengkulu. A completely randomized design was employed with one experimental factor, namely the amount of Gerga (*Citrus* sp.) peel powder added to the candle formulation. Four treatments were evaluated: P0 (0 g), P1 (1 g), P2 (2 g), and P3 (3 g), with three replicates for each treatment. The formulations differed only in the amount of Gerga peel powder incorporated into the candle base. The experimental units were randomly assigned to the treatments and maintained under uniform laboratory conditions to minimize the effects of extraneous variables.

Equipment and Materials

The principal equipment included an analytical balance, a calibrated gas-heating system, a water bath, stainless-steel crucibles, small glass molds, candle wicks, mechanical wick stabilizers, a grinder, a 40-mesh sieve, glass capillary pipettes, a 0–100 °C mercury thermometer, a graduated cylinder, a digital stopwatch, a 70 cm × 70 cm × 70 cm glass exposure chamber, and mosquito-maintenance containers. The materials were technical-grade solid paraffin, pure stearic acid, and a 10% (w/v) sucrose solution. The botanical active material was dried Gerga peel powder (*Citrus* sp.) collected from a local horticultural plantation at 3.294828° S and 102.419388° E. Adult *Aedes aegypti* mosquitoes were used as the test organisms.

Preparation of Dried Gerga Peel Powder

Gerga peel (*Citrus* sp.) were first washed under running water to remove surface debris. The albedo was separated manually, after which the peels were sun-dried until brittle and readily broken (Caputo et al., 2022). The dried peels were ground intermittently to limit heat buildup during milling and thereby reduce the loss of volatile compounds. The resulting powder was passed through a 40-mesh sieve to obtain a more uniform particle size (Baviskar et al., 2024). The dried peel powder was then stored in an airtight container until it was used as the active ingredient in the mosquito-control candles.

Formulation and Preparation of Mosquito-Control Candles

Four formulations—P0, P1, P2, and P3—were prepared in this study. The composition of each treatment is presented in Table 1.

Table 1. Formulations of mosquito-control candles containing Gerga peel powder.

Treatment	Formulation composition
P0	5 g paraffin + 5 g stearic acid
P1	5 g paraffin + 5 g stearic acid + 1 g Gerga peel
P2	5 g paraffin + 5 g stearic acid + 2 g Gerga peel
P3	5 g paraffin + 5 g stearic acid + 3 g Gerga peel

Candle preparation began by weighing the paraffin and stearic acid according to the specified formulation. The stearic acid was first melted in a water bath, followed by the addition of paraffin. The mixture was continuously stirred until the candle base had melted completely and became homogeneous. After being removed from the water bath, the molten mixture was allowed to cool briefly. Gerga peel powder was then incorporated at amounts of 1 g for P1, 2 g for P2, and 3 g for P3, followed by continuous stirring to ensure uniform dispersion. The resulting mixture was poured into small glass molds containing centrally positioned wicks. Each wick was supported in an upright position using a wooden holder until the candle had completely solidified at room temperature.

Physical Characteristics of the Candles

The physical characteristics of the mosquito-control candles were evaluated descriptively through visual

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inspection after complete solidification at room temperature. The parameters assessed included shape, firmness, color, surface condition, and the presence of air bubbles. Shape was evaluated based on conformity to the mold and the presence of deformation. Firmness was assessed based on the candle's ability to retain its shape at room temperature and under light pressure. Color uniformity was examined throughout the candle, while the surface was inspected for cracks, holes, and textural irregularities. The presence of air bubbles on the surface and within the candle was also recorded.

Melting Point Test

The melting point of the candles was determined using a glass-pipette method adapted with modifications from Zuddin et al. (2019). Molten candle material was drawn into a glass pipette to form a column approximately 3 cm in height and was then left for 16 h to solidify completely. The filled pipette was secured parallel to a mercury thermometer using a rubber band, with the lower end of the pipette aligned with the thermometer bulb. The assembly was positioned vertically in a beaker containing 500 mL of water and heated gradually over low heat. The temperature was monitored until the candle material inside the pipette began to melt. The temperature observed at the onset of melting was recorded as the melting point. Each treatment was tested in triplicate.

Burning-Time Test

Burning time was determined using a method adapted with modifications from Rusli and Rerung (2018). Each candle was lit in a draft-free room, and a stopwatch was started immediately after ignition. The stopwatch was stopped when the flame extinguished naturally or could No. longer be maintained. The burning time was recorded in minutes, and each treatment was tested in triplicate.

Hedonic Test

The hedonic test was conducted using a questionnaire adapted with modifications from Chotimah et al. (2024). A preliminary hedonic evaluation was conducted with ten voluntary panelists to evaluate their acceptance of the mosquito-control candles based on physical shape, color, aroma before burning, and aroma during burning. A four-point hedonic scale was used, where 1 indicated "strongly dislike," 2 indicated "dislike," 3 indicated "like," and 4 indicated "strongly like" (Fauzi et al., 2025). The scores obtained were converted into percentages and interpreted according to the acceptance categories presented in Table 2.

Table 2. Panelist acceptance categories.

Percentage (%)	Category
81-100	Strongly like
61-80	Like
41-60	Dislike
≤40	Strongly dislike

Mortality Test of *Aedes aegypti*

The *Aedes aegypti* mortality test was conducted in a ventilated glass exposure chamber measuring 70 cm × 70 cm × 70 cm to maintain air circulation during testing. Twenty adult *Aedes aegypti* were introduced into the chamber for each experimental unit. One mosquito-control candle corresponding to the assigned treatment was placed at the center of the chamber floor and burned for 60 min. Four treatment levels were tested in triplicate, requiring a total of 240 mosquitoes.

After exposure, all mosquitoes were transferred to maintenance containers and supplied with 10% sucrose solution as a nutrient source during the 24-h observation period. At the end of this period, the number of dead mosquitoes in each treatment was recorded. Mortality percentage was calculated from the number of dead mosquitoes relative to the total number tested in each experimental unit. It was used to evaluate the effectiveness of the mosquito-control candles against *Aedes aegypti* (Verentika et al., 2025).

Data Analysis

Data on physical characteristics and hedonic acceptance were analyzed descriptively. Quantitative data comprising melting point, burning time, and *Aedes aegypti* mortality percentage were analyzed statistically using computer software. Before inferential analysis, normality was assessed with the Shapiro–Wilk test and variance homogeneity with Levene's test.

Normally distributed data with homogeneous variances were analyzed using one-way analysis of variance (one-way ANOVA), followed by Tukey's post hoc test when significant differences were detected among treatments. When the assumptions of normality and/or homogeneity of variance were not satisfied, the Kruskal–Wallis test was applied. All statistical tests used a 5% significance level ($\alpha = .05$).

RESULTS AND DISCUSSION

Physical Characteristics, Melting Point, and Burning Time

Physical characteristics of the candles

Visual observations showed that the mosquito-control candles containing Gerga peel powder had satisfactory physical characteristics across all treatments (P0–P3). Every candle retained the complete shape of its mold,

showed no deformation during cooling or at room temperature, and remained firm under light pressure.

The color of each formulation was evenly distributed over the surface and throughout the interior. The candle surfaces were smooth and level, with no visible cracks or holes. No air bubbles were detected either on the surface or within the candles. Overall, all treatments produced candles with consistent physical characteristics. The detailed observations are presented in Table 3.

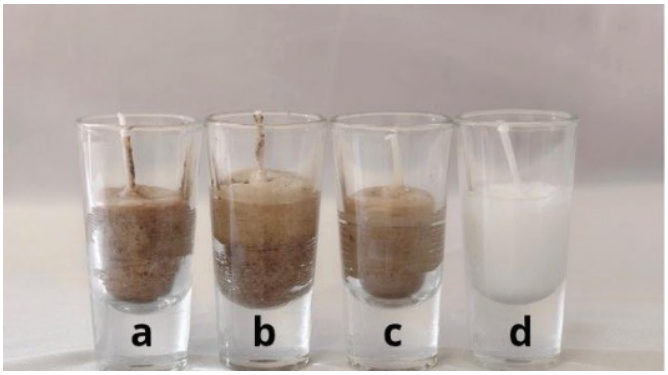


Figure 1. Candle products (a = P3, b = P2, c = P1, and d = P0)

Table 3. Physical characteristics of mosquito-control candles containing Gerga peel powder.

Characteristic	Description
Shape	Candles in all treatments (P0–P3) completely and neatly conformed to the molds and showed no deformation during cooling or at room temperature.
Firmness	All candles exhibited good firmness, retained their shape at room temperature, and did not deform under light pressure.
Color	P0 was milky white, with uniform color throughout. P1 was light cream, with homogeneous color distribution. P2 was brownish cream and visibly darker than P1. P3 was brown, had the greatest color intensity among treatments, and appeared homogeneous.
Surface condition	The surfaces of all candles were smooth and level, with no cracks or holes.
Air bubbles	No air bubbles were observed on the surface or within any candle (P0–P3), indicating that molding proceeded properly.

Overall, adding up to 3 g of Gerga peel powder did not impair the basic physical characteristics of the candles. All formulations solidified properly, had smooth surfaces, showed neither cracking nor deformation, and displayed uniform coloration. These observations indicate that, within the concentrations tested, the powder did not compromise the structural integrity of the paraffin–stearic acid candle matrix.

This stability may be attributable to the ability of paraffin and stearic acid to form a stable wax matrix in which the powder particles can disperse without disrupting solid-structure formation. During cooling, both base materials crystallize into a solid network, enabling the candles to maintain their shape and firmness despite the presence of Gerga peel powder. Agogué et al. (2022) similarly reported that changes in candle composition can influence crystalline microstructure, hardness, and physical stability. Nevertheless, formulations that remain predominantly composed of paraffin and stearic acid generally retain satisfactory physical properties.

Melting point

The melting-point test identified the temperature at which the candles began to change from the solid to the liquid phase. Mean melting points differed descriptively among treatments, as shown in Table 4.

Table 4. Mean melting points of mosquito-control candles containing Gerga peel powder.

Treatment	Melting point Mean ± SD (°C)
P0	54.0 ± 4.58
P1	53.7 ± 1.53
P2	56.3 ± 2.89
P3	64.3 ± 4.04

Melting point is an important indicator of candle quality because it is associated with product stability during storage and use. Candles with higher melting points are generally more resistant to softening at ambient temperatures (Liu et al., 2022). The mean melting points of P0, P1, P2, and P3 were 54.0 °C, 53.7 °C, 56.3 °C, and 64.3 °C, respectively. Values for P0, P1, and P2 remained within the commonly reported range of 44–57 °C for mosquito-control candles, whereas P3 had a higher melting point (Rusli & Rerung, 2018). However, the Kruskal-Wallis test indicated that the differences among treatments were not statistically significant ($p = .080$). Thus, adding up to 3 g of Gerga peel powder did not significantly alter the candle melting point.

Descriptively, the mean melting point tended to rise as the concentration of Gerga peel powder increased, particularly in P3. The increase may reflect the larger solid fraction within the wax matrix, which would require more thermal energy to initiate melting. Solid fillers can alter the thermal behavior of a paraffin matrix by modifying its internal structure and the interactions between the filler and the continuous phase (Gibson, 2016). Nevertheless, the observed trend was not statistically significant.

The absence of a significant difference indicates that paraffin and stearic acid, as the principal candle constituents, exerted a stronger influence than the added Gerga peel powder. Adding up to 3 g of powder was therefore insufficient to produce a consistent change in

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the thermal properties of the candles. This finding is consistent with Wusnah et al. (2025), who noted that candle melting point is governed by the composition and relative proportions of the formulation ingredients.

The tendency toward a higher melting point at greater powder concentrations suggests possible improvement in candle stability at ambient temperatures. Conversely, an excessively high melting point may affect wax liquefaction during burning and, in turn, the release of active constituents from Gerga peel. Further studies using a broader concentration range are needed to identify a formulation that balances physical stability with mosquito-control effectiveness.

Burning time

Burning time was measured from the ignition of the wick until the flame extinguished naturally. The mean burning times varied descriptively among the treatments, as presented in Table 5.

Table 5. Burning times of mosquito-control candles containing Gerga powder.

Treatment	Burning time Mean ± SD (min)
P0	110.66 ± 61.99
P1	67.52 ± 24.15
P2	49.01 ± 18.39
P3	75.65 ± 22.39

P0 had the longest mean burning time (110.66 min), whereas P2 had the shortest (49.01 min). Descriptively, candles without Gerga peel powder tended to burn longer than formulations containing the powder. Variation among replicates within each treatment was nevertheless substantial. The Shapiro–Wilk test showed that the P0 and P3 data were not normally distributed ($p < .05$); therefore, the Kruskal–Wallis test was used. The resulting significance value was .505 ($p > .05$), indicating that adding up to 3 g of Gerga peel powder did not significantly affect burning time.

Candle burning time is influenced by several factors, including ingredient composition, wick characteristics, and combustion conditions (Furlong et al., 2023). In the present study, formulations containing Gerga peel powder tended to burn for less time than the control. The powder-free candle had the longest burning time, whereas powder-containing treatments generally burned for shorter periods. This pattern may be related to changes in the physical properties of the wax matrix caused by the addition of a solid filler, which can affect wax melting during combustion. Musdar et al. (2024) likewise showed that incorporating additional materials into a candle formulation can modify its burning time.

Increasing the amount of Gerga peel powder did not result in a linear change in burning time. P3, which contained 3 g of Gerga peel powder, had a longer mean burning time than P2, although both formulations contained the powder. This pattern suggests that burning time was influenced not only by the amount of powder added but also by other factors involved in the combustion process. Interactions among the wax matrix, wick, and filler may affect wax melting and its transport toward the wick, thereby producing different combustion patterns among the formulations (Furlong et al., 2023). However, because this mechanism was not directly investigated in the present study, it cannot be confirmed as the cause of the longer burning time observed in P3.

The nonsignificant differences among treatments show that variation in Gerga peel powder content up to 3 g did not consistently alter candle-combustion behavior. In addition to composition, combustion is affected by interactions among the wax, wick, and container (Oktarina et al., 2021). The use of small glass containers permits a melt pool to form, which influences heat distribution during burning (Furlong et al., 2023). Variability in these conditions may have contributed to the large differences in burning time among replicates.

Taken together, the results demonstrate that adding up to 3 g of Gerga peel powder did not significantly influence the burning time of the mosquito-control candles. Studies using a wider range of powder concentrations and more tightly controlled combustion conditions are required to clarify how the powder affects candle-burning characteristics.

Mortality of *Aedes aegypti*

The mortality test evaluated the effectiveness of candles containing Gerga peel powder in inducing mortality in *Aedes aegypti*. Mortality was determined based on the number of mosquitoes that died during the 24-h observation period following candle exposure. During this period, the mosquitoes were maintained on a 10% sugar solution. Mortality rates varied among the treatments, as presented in Table 6.

Table 6. *Aedes aegypti* mortality after exposure to mosquito-control candles containing Gerga peel powder.

Treatment	Mean ± SD (mosquitoes)
P0	0.00 ± 0.00^{a}
P1	4.67 ± 1.53^{ab}
P2	7.67 ± 2.52^{bc}
P3	12.33 ± 3.51^{c}

Note: Values followed by different superscript letters within the same column differ significantly according to Tukey's test at the 5% significance level.

As shown in Table 6, P0 (control) produced the lowest mean mortality, with no mosquitoes dying. Mean mortality in P1, P2, and P3 was 4.67, 7.67, and 12.33 mosquitoes, respectively, corresponding to mortality rates of 23%, 38.33%, and 62%. Mortality therefore tended to increase with the amount of Gerga peel

powder incorporated into the candle formulation. Within the tested concentration range, this pattern suggests a dose–response relationship in which a larger number of mosquito deaths accompanied greater powder concentrations.

Before hypothesis testing, the mortality data were assessed for normality and homogeneity of variance. The assumptions required for one-way ANOVA were met. The analysis showed that the amount of Gerga peel powder significantly affected *Aedes aegypti* mortality ($p < 0.05$). Tukey's post hoc test revealed that P2 and P3 differed significantly from the control treatment (P0), whereas P1 did not differ significantly from P0, P2, or P3. No mortality was recorded in the control treatment. This result suggests that the mortality observed in the powder-containing treatments was unlikely to have resulted solely from combustion heat or chamber conditions and may have been associated with bioactive constituents released from Gerga peel powder.

One-way ANOVA indicated a significant difference in mosquito mortality among treatments ($F(3,8)=15.344$, $p=0.001$). Mortality percentages based on 20 mosquitoes per chamber were 0%, 23.33%, 38.33%, and 61.67% for P0, P1, P2, and P3, respectively. Tukey HSD was used for post hoc comparison.

The observed insecticidal activity may be associated with secondary metabolites present in citrus peel, including limonene, citral, linalool, terpenoids, phenolic compounds, and flavonoids. These compounds have been reported to exert insecticidal effects by interfering with insect physiological systems (Andriani & Rendowaty, 2024). During combustion, heat may facilitate the release of some volatile compounds from the dried peel powder into the air, thereby exposing the mosquitoes in the chamber to these substances. The higher mortality observed at greater amounts of Gerga peel powder may indicate increased exposure to active compounds, resulting in a stronger insecticidal effect. However, the release and concentration of these compounds in the chamber were not directly measured in the present study.

The highest mortality rate observed in this study was approximately 62%, indicating that the candles exhibited partial effectiveness under the experimental conditions. Some mosquitoes remained alive throughout the 24-h observation period. This limited effectiveness may be related to the use of dried peel powder as the active material, which might not have released its volatile constituents efficiently during combustion. Some bioactive compounds may also have remained within the wax matrix or plant tissue, thereby reducing the amount dispersed into the chamber air. However, the release and airborne concentrations of these compounds were not directly measured in this study.

This finding is consistent with that of Dewi et al. (2025), who reported that bioactive compounds derived from citrus peel significantly affected *Aedes aegypti* mortality. However, their study used essential oil as the active ingredient, allowing volatile constituents to evaporate more readily than those contained in dried peel powder. This difference suggests that the physical form of the active ingredient may influence its release and, consequently, the effectiveness of mosquito-control candles.

Overall, Gerga peel powder shows potential as a botanical active ingredient in mosquito-control candle formulations. The higher mortality observed in treatments containing greater amounts of powder supports the further development of this plant-based formulation. Nevertheless, the tests were conducted in a controlled chamber; therefore, the findings cannot yet be generalized to outdoor or household conditions. Further research should evaluate a wider range of powder amounts, optimize the formulation, and directly compare dried peel powder with citrus extracts or essential oils to improve mosquito-control effectiveness.

Hedonic Test

The hedonic test assessed panelist acceptance of the mosquito-control candles containing Gerga peel powder. Ten panelists evaluated four attributes: shape, color, aroma before burning, and aroma during burning. Scores were converted to acceptance percentages and classified according to the hedonic categories. The results are presented in Table 7.

Table 7. Hedonic-test results for mosquito-control candles containing Gerga peel powder.

Treatment	Shape	Color	Aroma	
			Before burning	During burning
P0	67%	53%	25%	25%
P1	75%	68%	59%	53%
P2	77%	77%	70%	70%
P3	86%	87%	88%	96%

The hedonic results indicate that adding Gerga peel powder improved panelist acceptance of the mosquito-control candles. This pattern was evident for all evaluated attributes: shape, color, aroma before burning, and aroma during burning. P3 received the highest acceptance for every attribute, whereas P0 received the lowest. Increasing the powder concentration therefore did not reduce sensory quality; rather, it enhanced overall acceptance.

Improved visual acceptance indicates that incorporating Gerga peel powder still produced candles with an appealing appearance. All formulations retained an intact, stable shape, while the powder-containing candles developed colors that panelists found more attractive than the control. Thus, powder addition did not interfere with candle formation or visual quality and maintained a favorable appearance.

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Aroma showed the most pronounced difference in acceptance. As the Gerga peel powder concentration increased, panelists expressed greater liking for the candle aroma both before and during burning. The citrus fragrance likely originated from volatile constituents such as limonene, citral, and linalool that continued to be released during combustion. These compounds impart a fresh, characteristic aroma that may improve comfort during use. Yerizam et al. (2022) similarly reported that volatile components from citrus peel can increase panelist acceptance of candle aroma.

Notably, the formulation most favored by panelists also produced the highest *Aedes aegypti* mortality. This finding indicates that a greater concentration of Gerga peel powder can yield a formulation with both favorable sensory quality and biological activity. The study was not designed, however, to test the relationship between panelist acceptance and candle bioactivity; this association therefore requires further investigation.

Testing was performed in a chamber with limited ventilation, so the results may not fully represent use in open spaces or household environments. The study also did not identify the volatile constituents released during burning, assess product stability during storage, or quantify the release rate of active compounds from the wax matrix. Further research should therefore characterize the compounds emitted during combustion, evaluate effectiveness under a wider range of use conditions, and optimize mosquito-control candle formulations containing Gerga peel powder.

Study Limitations

Study limitations should be considered when interpreting these findings. The mosquito bioassay was performed under laboratory conditions; however, temperature, relative humidity, and light intensity were not measured. The susceptibility status of the mosquito colony was also not evaluated. Furthermore, initial candle masses differed among treatments (P0=10 g, P1=11 g, P2=12 g, and P3=13 g). Although the same mold was used, final candle mass and exact dimensions were not measured. Botanical authentication and voucher specimen documentation were unavailable; therefore, the material is reported as *Citrus* sp.

CONCLUSION

Adding Gerga peel powder (*Citrus* sp.) produced mosquito-control candles with satisfactory physical characteristics and did not significantly affect melting point or burning time. The powder concentration significantly influenced *Aedes aegypti* mortality, with P3 producing the highest mean mortality. P3 also received the highest panelist acceptance for shape, color, aroma before burning, and aroma during burning. These results demonstrate the potential of Gerga peel powder as a botanical active ingredient for mosquito-control candles that combine acceptable physical quality, increased *Aedes aegypti* mortality, and high sensory acceptance.

CONCLUSION

Adding Gerga peel powder (*Citrus* sp.) produced mosquito-control candles with satisfactory physical characteristics and did not significantly affect melting point or burning time. The powder concentration significantly influenced *Aedes aegypti* mortality, with P3 producing the highest mean mortality. P3 also received the highest panelist acceptance for shape, color, aroma before burning, and aroma during burning. These results demonstrate the potential of Gerga peel powder as a botanical active ingredient for mosquito-control candles that combine acceptable physical quality, increased *Aedes aegypti* mortality, and high sensory acceptance.

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