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Research Article
Insecticidal Effects of Extracts from Three Herbal Plants on the Poultry Pest *Alphitobius diaperinus*

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Abstract
Background and Objective: *Alphitobius diaperinus* (Coleoptera: Tenebrionidae) is a major pest in conventional chicken farms in Indonesia. The temperature and humidity in the cage should be similar to their habitat. To find bioinsecticidal plants that can be integrated into the chicken house area, this study aims to analyze phytochemical compounds, test toxic effects and repellents of three types of herbal plants, i.e., *Lantana camara*, *Evodia suaveolens* and *Pluchea indica* against adult *A. diaperinus*. **Materials and Methods:** Toxic and repellent effects of extracts were tested at five concentrations. Toxicity indicators were analyzed based on mortality 2×24 hrs post-exposure. The estimated LC_{50} of the extracts was calculated from the mortality data at 48 hrs post-exposure. Repellency was observed using a Y-olfactometer tube to obtain the repellency (PR) data percentage. A two-way ANOVA test was conducted to identify significant treatments, using a significance level 0.05. **Results:** Phytochemical analysis revealed insecticidal compounds in the three leaf extracts. The leaf extracts of *E. suaveolens*, *L. camara* and *P. indica* showed an estimated LC_{50} value of 24 hrs at concentrations of 86.11, 91.33 and 97.51%, respectively. Extract concentrations affected PR with significant differences (Tukey's range test; $p<0.05$) and *E. suaveolens* extract showed the best repellency. **Conclusion:** All extract sources contain insecticidal compounds, but toxicity and repellency test results show the best LC_{50} and repellency estimates for *E. suaveolens* extracts. Thus, *E. suaveolens* extract has the potential to control and repel the poultry pest *A. diaperinus* and this plant can be integrated around conventional chicken cages.

Key words: *Alphitobius diaperinus*, bioinsecticide, herbal plant, repellent, toxicity

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The poultry pest *Alphitobius diaperinus* (Coleoptera: Tenebrionidae) is a shed pest insect that breeds in chicken houses. In Indonesia, the larvae are known as lesser mealworms. These insects consume chicken feed and make hiding places in the infrastructure of the building to lay eggs and the larvae pupate. Larvae and adults are known to be vectors of chicken diseases such as Marek's disease, infectious bursal disease, Newcastle disease, fowl pox, avian influenza and carriers of parasites[1]. The presence of *A. diaperinus* is facultative, with the population being very high when the cage is producing and decreasing or even disappearing when the cage is empty. Facultative insect control is more difficult because fumigation, when the cage is empty, is considered ineffective and less targeted[2].

In Indonesia, *A. diaperinus* control is generally based on second-generation chemical insecticides, namely organophosphates, carbamates and pyrethroids. These synthetic insecticides can cause insect resistance, harm poultry and cause contamination of poultry houses[3]. In addition, second-generation insecticides continue to cause environmental problems with chemical residues that threaten the environment and the survival of non-target organisms. Therefore, efforts to find effective and environmental friendly insecticide sources are still the focus of researchers to produce bioinsecticides. Bioinsecticides are a type of insecticide whose active ingredients are derived from nature, including animals, plants, microbes and minerals[4]. As an agricultural country, Indonesia has the potential to develop bioinsecticides due to its rich biological resources.

The mode of action of bioinsecticide molecules does not kill insects directly but damages their physiological processes in various ways, which results in stopping their life cycle[5]. According to Mahawer *et al.*[6], the performance of bioinsecticides includes causing repellent effects, damaging feeding behavior (antifeedant), reducing viability, disrupting growth, inhibiting reproduction, disrupting the process of metamorphosis, or being toxic, which causes death in target insects.

In Indonesia, *E. suaveolens*, *L. camara* and *P. indica* are classified as medicinal plants. These plants usually grow wild and are used as replacement plants for garden fences. *Evodia suaveolens* is native to Indonesia and belongs to the Rutaceae family, *L. camara* belongs to the Verbenaceae family and *P. indica* belongs to the Asteraceae family. *Evodia suaveolens* leaves taste bitter, emit a distinctive aroma that is volatile and is widely used as a mosquito repellent[7-9]. These three plants contain triterpenoids[10-12], which have insecticidal activity against various types of pests, so they have potential as bioinsecticides against plant and stored product pests. On the other hand, *E. suaveolens*, *L. camara* and *P. indica* plants are often found growing wild in poultry house areas and become boundary fences. This study aimed to analyze the extent to which *E. suaveolens*, *L. camara* and *P. indica* leaf extracts provide toxic and repellent effects against *A. diaperinus* beetles. The results of the study are expected to provide important information for the integration of herbal plants in poultry house areas so that they have dual benefits as intercrops and suppress the development of the poultry pest *A. diaperinus*.

MATERIALS AND METHODS

Study area: The research was conducted between January and April, 2024 in the experimental cages at the Biology Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia. The study was a laboratory experimental design using *A. diaperinus* beetle as test subjects. The test materials were ethanol extracts of *E. suaveolens*, *L. camara* and *P. indica* leaves collected from Temu Gesang herbal garden, Magelang (Indonesia). The preparation and implementation of the study were carried out in several stages based on the observed variables as follows.

Preparation of plant extracts: The dried leaf powder of three herbal plants was each macerated with ethanol solvent at a ratio of 1:4 (w/v) for 3×24 hrs. The ethanol extracts were then evaporated at low pressure using a rotary evaporator (BUCHI R-220Pro, Switzerland), to obtain concentrated extracts and stored at temperatures below 5°C until further use. The concentrated extract obtained was considered to be 100% ethanol extract. To obtain a lower concentration in the treatment, the solvent aqua test was used.

Phytochemical analysis: Phytochemical analysis of the extracts was performed using the PerkinElmer 2400 GC-MS (USA) method, which consists of an AOC-20i autosampler and a Gas Chromatograph coupled with a Mass Spectrometer (GC-MS). The relative percentage of each component was calculated by comparing the average peak area to the total area. The mass detector used in this analysis was Turbo-Mass Gold-Perkin-Elmer and the software used to process the mass spectra and chromatograms was Turbo-Mass ver-5.2. The phytochemicals were identified based on their retention time, percentage of peak and area pattern of mass spectra and their comparison with the data of the National Institute of Standards and Technology (NIST) library.

Collection of insects: Test insects (adult *A. diaperinus*) were collected from lesser mealworm farmers in the Banyu Manik area of Semarang, then kept in insect containers and fed with commercial chicken feed. The adult *A. diaperinus* that were used as samples were selected to be black and to be relatively uniform in size (5-6 mm).

Toxicity test: Toxicity tests were conducted on adult cage bugs and measured based on the number of insect deaths at 24 and 48 hrs after exposure to the extract. The extract was tested in 6 treatments, namely concentrations of 0, 20, 40, 60, 80 and 100%; each unit used 50 ticks and repeated five times. Exposure to the extract was performed by dripping 200 µL of the extract onto 1×1 cm filter paper, which was then placed in a plastic cup (5 cm diameter, 4.5 cm height). *A. diaperinus* was placed in the cup to allow direct interaction between the insect and the extract. In this experiment, $3\times6\times5 = 90$ experimental units were required for a total insect population of $90\times50 = 4500$ adult *A. diaperinus*. Each plastic cup was then filled with 2.5 g of pollard and incubated in a room protected from sunlight. After 24 hrs, *A. diaperinus* exposed to the extract was observed and the number of dead ticks was recorded. Observations were made in the morning, 48 hrs after exposure to the extract. Mortality is calculated as a percentage, i.e., the number of deaths divided by the number of test samples multiplied by 100%.

If the mortality of *A. diaperinus* in the control group was less than 5%, the data were statistically analyzed directly, but if the mortality was between 5 and 20%, the data had to be corrected using Abbott's correction[13]. Mortality data were also used to estimate the lethal concentration (LC_{50}) of extracts within 24 and 48 hrs.

Repellent effect: The repellent effect of the three leaf extracts was observed using a Y-olfactometer tube designed to have three interconnected passages. The length of each passage is 20 cm. Aisle A was where the test animals were placed, aisle B was for the control and C was for the placement of the treatments. The extract was tested in 5 treatments, namely concentrations of 20, 40, 60, 80 and 100%, each as much as 200 µL and dripped onto 1×1 cm filter paper. The filter paper exposed to the extract was placed at the end of aisle C, while the end of aisle B received only filter paper without extract. A total of 30 adult test insects were introduced through Aisle A and observed as they exited through aisle B or C. Insects that showed behavior rejecting the presence of extracts will avoid and turn around, looking for another exit (aisle B). The preference test was conducted for 30 min and repeated five times. Percent repellency (PR) was calculated using the following formula[14]:

$$\text{PR (\%)} = \frac{\text{Nc} - \text{Nt}}{\text{Nc} + \text{Nt}} \times 100$$

Where:

PR = Percentage of repellent
Nt = Number of insects entering the treatment aisle
Nc = Number of insects entering the control aisle

Statistical analysis: Data on 24 hrs mortality and PR were analyzed using SPSS 21 software. A two-way ANOVA test was used to identify significant treatments. Mortality data were probit analyzed to obtain the estimated LC_{50} value. The PR value was analyzed descriptively concerning the criteria of Aref and Valizadegan[15], who used five criteria to determine the high and low repellency of a material namely: (a) Very low repellency when $0.1<\text{PR}\leq20\%$; (b) Low repellency when $20\%<\text{PR}\leq40\%$; (c) Moderate repellency when $40\%<\text{PR}\leq60\%$, (d) High repellency when $60\%<\text{PR}\leq80\%$ and (e) Very high repellency when $\text{PR}\geq80\%$.

RESULTS AND DISCUSSION

Phytochemical screening of extracts: The results of phytochemical analysis of *E. suaveolens*, *L. camara* and *P. indica* leaf extracts by GC-MS method are shown in Table 1 and 2.

Based on the results of phytochemical analysis (Table 1 and 2), it show that *E. suaveolens* extract was detected to contain compounds of alkaloids, terpenoids, steroids and saponins groups. The results of the GC-MS test showed that *E. suaveolens* leaf extract was found to contain phytol, junenol and piperine compounds with peak areas of 23.35, 11.97 and 8.89%, respectively. These three compounds are terpenoids that cause a distinctive and strong aroma to insects. From *L. camara* leaf extract, two kinds of compounds with high percentages were phytol and squalene, which are sesquiterpene groups. The highest compound found in the leaf extract of *P. indica* was Desulphosinigrin, a compound alkaloid, which has strong biological activity.

Compounds in the alkaloids, steroids, terpenoids, flavonoids, tannins and saponins groups are known to have anti-insect properties. Saponins have good detergent properties and are toxic to insects. The mechanism of action of saponin compounds is through two pathways, including through contact with poison and the respiratory system's

Table 1: Qualitative phytochemical analysis results

Parameter	*Evodia suaveolens*	*Lantana camara*	*Pluchea indica*
Alkaloids	+	-	+
Flavonoids	-	+	+
Steroids	+	+	+
Terpenoids	++	+	-
Saponins	+	-	+
Tannins	-	+	-

Qualitative phytochemical analysis (Laboratory of Organic Chemistry, FMIPA UNNES, 2024), +: Detected and -: Not detected

Table 2: List of major compounds identified from the three extracts tested by GC-MS analysis

Number	RT (min)	Compound name	Chemical formula	Peak area (%)
***Evodia suaveolens* leaf extract**				
1	13.49	Junenol	$C_{15}H_{26}O$	11.97
2	18.52	Phytol	$C_{20}H_{40}O$	23.35
3	24.12	Squalene	$C_{30}H_{50}$	4.06
4	25.05	Piperine	$C_{17}H_{19}NO_3$	8.89
5	29.71	β-Sitosterol	$C_{29}H_{50}O$	8.97
***Lantana camara* leaf extract**				
1	11.02	Caryophyllene	$C_{15}H_{24}$	5.43
2	18.50	Phytol	$C_{20}H_{40}O$	18.08
3	24.12	Squalene	$C_{30}H_{50}$	16.83
4	25.09	1,3-Dioxolane, 2-pentadecyl	$C_{18}H_{36}O_2$	8.05
5	29.70	Ethyl iso-allocholate	$C_{26}H_{44}O_5$	10.62
***Pluchea indica* leaf extract**				
1	10.74	Gentamicin	$C_{18}H_{36}N_4O_{10}$	5.87
2	13.45	Paromomycin	$C_{23}H_{45}N_5O_{14}$	3.27
3	14.35	Desulphosinigrin	$C_{10}H_{17}NO_6S$	23.08
4	18.78	9-Hexadecenoic acid	$C_{16}H_{30}O_2$	4.45
5	21.39	Ethyl iso-allocholate	$C_{26}H_{44}O_5$	2.46

Results of GC-MS screening at LPPT UGM, Yogyakarta, 2024

stomach. Through contact poison, this compound will irritate the mucous membranes in the larval stage. Saponins also cause the failure of the larval molting process because saponins can bind sterols in the food channel, resulting in a decrease in the rate of sterols in the hemolymph[16,17]. Phytol belongs to the terpenoid class and is the major component of many essential oils from plant extracts. Phytol compounds are also known as aroma producers, which are thought to have repellent and antifeedant activities[18]. All three extracts tested also contained steroids (Table 1). Steroids are growth hormones that affect the molting of larvae[19]. Therefore, steroids have toxic properties that can inhibit the molting process in insects[20]. Tannins are generally complex chemicals derived from phenolic acids and are natural polyphenolic compounds in plants[21]. Tannins are highly detrimental to insects because they can inhibit insect growth and development by binding to proteins, reducing the ability to absorb nutrients and inducing midgut lesions. Tannins are bitter polyphenols that can reduce appetite, are effective feeding deterrents for many insect pests and play a role in inhibiting gastrointestinal enzymes, namely proanthocyanidins[22].

Tannins are among the astringent-type compounds (chemical compounds with the ability to cause bitterness, stinging on the tongue and a feeling of shrinking or dryness in body tissues) because they contain polyphenolic groups that can bind, precipitate, or shrink proteins[23]. Tannins affect insects by acting as antifeedants and by inhibiting the action of protease enzymes. When tannins enter the insect's body, they bind to proteins that are catalyzed by these enzymes, causing digestive system disorders. If this happens regularly, it can increase the risk of insect mortality[24]. More specifically, the protein is precipitated by tannins, rendering its function inactive by forming a tannin-protein complex and making it difficult for insects to digest[25]. Tannin compounds are usually possessed by plants to protect them from insects. How tannins work as antifeedants for larvae is also following the mechanism of inhibiting substances as described above[20,26]. Thus, based on previous statements and research results, it can be said that flavonoids, steroids, saponins and tannins have anti-insect properties with different mechanisms, so they have the potential to be used as bio-insecticides.

Toxicity test observation: Mortality at 24 hrs of observation showed a low rate, less than 50% and only the 100% concentration of *E. suaveolens* extract had reached 52%, namely the 100% *E. suaveolens* extract treatment. Furthermore, at 48 hrs, 50% mortality was found in the 80%

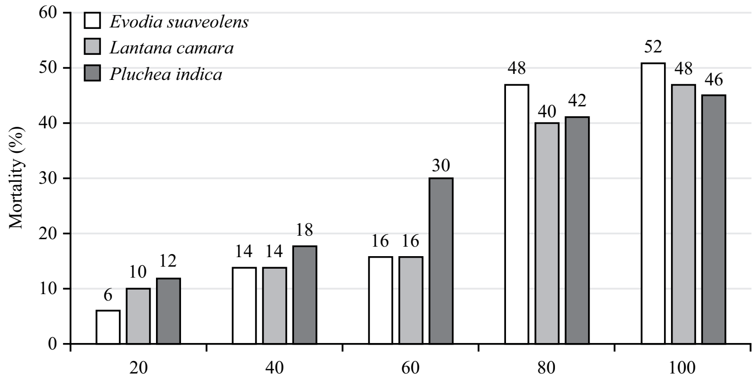

Fig. 1: Mortality of *A. diaperinus* adults at 24 hrs after exposure to extracts

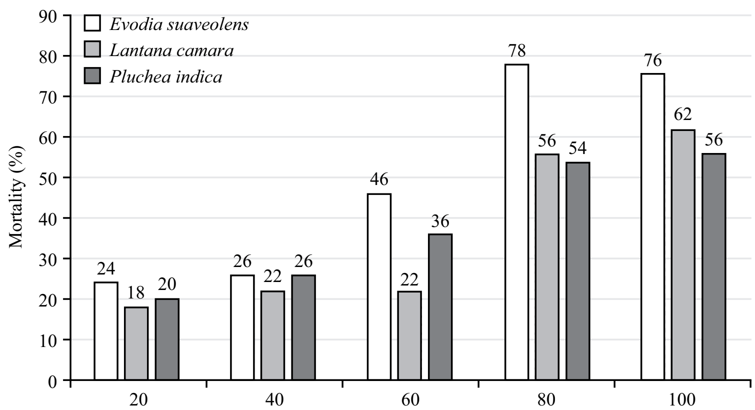

Fig. 2: Mortality of *A. diaperinus* adults at 48 hrs after exposure to extracts

extract treatment in all extract sources, but *E. suaveolens* leaf extract reached the highest rate (76%) compared to *L. camara* and *P. indica* leaf extracts (Fig. 1 and 2).

Increasing extract concentrations tended to increase mortality, but at 24 hrs only 100% concentration of *E. suaveolens* extract caused 50% mortality. Within 48 hrs, 80% concentration of extracts in all three types of extracts had shown >50% mortality, but *E. suaveolens* extract still showed the highest percentage of mortality, followed by *L. camara* and *P. indica*. This condition strengthens the indication that *E. suaveolens* extract contains the most active compounds compared to the other extracts (Table 1 and 2). *Evodia suaveolens* extract was found to contain phytol and piperine compounds, which are thought to cause a stronger aroma that is disliked by insects. According to Spochacz *et al.*[27], secondary metabolites produced by plants have a wide range of activities that can affect insects at the cellular, tissue and organ levels. Physiological effects include sublethal changes in various tissues and organs, which can ultimately lead to death. In addition, secondary metabolites may directly or indirectly reduce the number of individuals in the population through reduced fecundity, reduced viability or deformities in the parental and filial generations. Jayakumar *et al.*[28] reported that the synergistic effect of a mixture of phytochemical compounds present in plant extracts plays an important role in defense against insects. Some compounds, either individually or synergistically, provide antifeeding, toxicity or insecticidal properties.

One of the mechanisms of action of secondary metabolite compounds as self-protection against insect interference is to provide antifeedant effects that inhibit the response of receptor cells that are sensitive to feeding cues such as food craving or taste[28]. Direct exposure to the extract is likely to result in the active compounds in the extract entering the insect's respiratory system as a fumigant or hitting the insect's body directly and acting as a contact poison. Contact poisons work by damaging the physical exoskeleton (cuticle), causing insects to slowly lose body fluids and, within a period, can cause death[29,30].

To predict the LC_{50} value, the number of insect deaths at various concentration levels was analyzed by Probit analysis, with the results shown in Table 3.

Table 3: Estimated LC_{50} of *E. suaveolens*, *L. camara* and *P. indica* extracts at 24 and 48 hrs of observation

	Extract sources		
Estimate	*Evodia suaveolens*	*Lantana camara*	*Pluchea indica*
LC_{50} (24 hrs)	86.114	91.330	97.513
Lower bound	59.853	79.539	84.091
Upper bound	110.561	110.779	131.4485
LC_{50} (48 hrs)	72.313	92.253	101.026
Lower bound	59.099	79.923	69.734
Upper bound	82.827	113.535	248.344

Table 4: Average PR value of the three types of extracts tested as well as different extract concentrations

	PR-value (%)		
Extract concentration (%)	*Evodia suaveolens*	*Lantana camara*	*Pluchea indica*
20	45.6^{a}	31.6^{a}	31.6^{a}
40	68.4^{b}	69.2^{b}	40.6^{a}
60	85.6^{c}	85.6^{c}	70.4^{b}
80	91.2^{d}	87.2^{c}	83.6^{c}
100	96.0^{d}	94.8^{d}	87.6^{c}
Average	75.4^{a}	73.7^{a}	63.6^{b}

Different superscripts in columns or rows of means indicate significant differences according to Tukey's test at a 5% significance level

The estimated LC_{50} values for *E. suaveolens*, *L. camara* and *P. indica* extracts were observed at both 24 and 48 hrs. At 24 hrs, the LC_{50} values were 86.114, 91.330 and 97.513 for *E. suaveolens*, *L. camara* and *P. indica*, respectively, with their corresponding lower and upper bounds ranging from 59.853 to 110.561 for *E. suaveolens*, 79.539 to 110.779 for *L. camara* and 84.091 to 131.4485 for *P. indica*. At 48 hrs, the LC_{50} values decreased slightly for *E. suaveolens* (72.313), while *L. camara* (92.253) and *P. indica* (101.026) showed a modest increase. The lower and upper bounds for 48 hrs ranged from 59.099 to 82.827 for *E. suaveolens*, 79.923 to 113.535 for *L. camara* and 69.734 to 248.344 for *P. indica*. These results indicate a varying level of toxicity across the extracts over time, with *E. suaveolens* showing the lowest LC_{50} value after 24 hrs.

Evodia suaveolens leaf extract showed toxic effects by causing a higher percentage of mortality than *L. camara* and *P. indica* leaf extracts. *Evodia suaveolens* leaf extract has a high terpenoid content and emits a pungent odor. This compound is thought to be involved in the inhibition of biosynthetic processes, which is indicative of a neurotoxic effect that causes insects to limp and then die. Terpenoids also inhibit the pupal stage, preventing the emergence of adult insects[30].

The mechanism of action of natural bioinsecticides on insects is generally not direct killing. Although toxic, insects will give a reaction of several hours or more depending on the high and low concentration. In this study, the content of alkaloid, terpenoid, steroid and tannin compounds contained in *E. suaveolens* extract is believed to be the cause of death of *A. diaperinus* ticks. The active compounds in these extracts may act synergistically or may be the cause of death only occasionally. Synergistic effects can have a greater effect than the effect of a single compound[31]. Some of the active compounds in plants that can act as bioinsecticides or insect repellents are isoprene-derived terpenoids, followed by alkaloids and phenolics[32].

Repellency test observations: The repellent effect of the extract was measured based on the percentage repellency (PR) value of adult *A. diaperinus* and the results were shown in Table 4. The findings indicate that the PR values for all three extracts-*E. suaveolens*, *L. camara* and *P. indica*-tended to increase with higher extract concentrations. *Evodia suaveolens* exhibited the highest PR values across all concentrations, reaching a peak of 96.0% at 100%. *Lantana camara* followed closely, with a maximum PR value of 94.8% at 100%, while *P. indica* demonstrated the lowest PR values, with a maximum of 87.6% at the same concentration. The average PR values also reflected these trends, with *E. suaveolens* showing the highest average (75.4%), followed by *L. camara* (73.7%) and *P. indica* (63.6%). This suggests that *E. suaveolens* was the most effective among the extracts tested, while *P. indica* was the least effective overall.

Differences in extract source and extract concentration had a significant effect (sig<0.05) on the PR value. Using Tukey's difference test, it is known that the PR value is different in all concentration treatments. However, there was no significant difference between 80 and 100% concentration treatments. Similarly, when comparing the types of extracts, the PR value was significantly different between *E. suaveolens*, *L. camara* and *P. indica* extracts. The higher the concentration of extracts, the higher the PR value tends to increase, so in this study, the highest PR value was found in the 100% extract treatment in all types of extracts. The results of statistical analysis showed that different types of extracts had a significant effect (sig<0.05) and the results of Tukey's test showed that *E. suaveolens* extract had the highest repellent effect compared to the other two extracts. This is due to the content of insecticidal active compounds in *E. suaveolens* extract, especially terpenoids, which are found more than the other two extracts (Table 2). *Evodia suaveolens* extract was found to contain junenol, phytol, squalene and piperine, while *L. camara* leaf extract contained caryophyllene, phytol and squalene. Meanwhile, gentamicin a and paromomycin were found in *P. indica* extract. The difference in the variety of active compounds is thought to affect the level of aroma caused. *Evodia suaveolens*, *L. camara* and *P. indica* leaf extracts emit a pungent aroma, which is thought to be due to the content of volatile terpenoid group compounds.

Phytol compounds belong to the diterpenoid group[33] while lupeol contains triterpenoids, both of which are volatile and cause a pungent aroma[34,35]. As for piperine, it belongs to the group of alkaloids that give off an aroma that causes a pungent effect and this compound is commonly found in various plants[35]. The presence of these compounds strengthens the suspicion that *A. diaperinus* senses the strong aroma and tries to avoid it. Avoiding areas that produce the aroma is a form of *A. diaperinus* rejection response to *E. suaveolens*, *L. camara* and *P. indica* leaf extracts. Insect antennae are used not only to detect the direction of sex pheromone sources but also to detect chemicals they do not like[36]. According to Pichersky and Raguso[37], terpenoid compounds have a distinctive and strong odor that, when smelled, causes disturbances in the nervous and metabolic systems of insects. The antennae organs of *A. diaperinus* contain different types of sensors to detect stimuli, in this case, odor sensors. In general, these antennae can detect and identify compounds that are needed or avoided by insects.

The cell body of the sensory neuron in the insect's antenna transmits the stimulus down the axon to the central nervous system, then to the motor nerve to be translated into a response or behavior. *Alphitobius diaperinus* insects that exhibit avoidance behavior from the treated corridor indicate the presence of locomotor activity in the insect[38]. The neurotransmitter acetylcholine is initiated to stimulate muscle contraction to move the body of *A. diaperinus* to move away from the source of the odor by choosing the path to the left aisle where the aisle is controlled or odorless.

The strength of the repellent effect produced depends on the concentration levels received. In this study, the PR value is in line with the increasing concentration of the extract. The higher or more concentrated the concentration of the extract, the higher the percentage of repellency produced. This was in line with the findings of Abdellaoui *et al.*[39] that phytochemical compounds have an insecticidal effect (insect control), but the effect depends on the dose given. The PR value, according to Aref and Valizadegan[15] can be categorized into five criteria to classify the high and low repellency of a material namely: (a) Very low category repellency when $0.1<PR\leq 20\%$; (b) Low category repellency when $20\%<PR\leq 40\%$; (c) Medium category repellency when $40\%<PR\leq 60\%$, (d) High category repellency when the value of $60\%<PR\leq 80\%$ and (e) Very high category repellency when $PR\geq 80\%$. Based on these criteria, it can be concluded that *E. suaveolens* and *L. camara* leaf extracts at a concentration of 40% produced a high category repellent effect, while *P. indica* leaf extracts at a concentration of 60% produced a high-category repellent effect. Overall, *E. suaveolens* extract provided the highest repellency compared to the other two types of extracts.

CONCLUSION

Evodia suaveolens, *Lantana camara* and *Pluchea indica* extracts contain bio insecticidal active compounds, but the most active compounds were found in *E. suaveolens* extract. The three extracts provide toxic and repellent effects against adult *A. diaperinus*, but the most optimal toxic and repellent effects are found in the 80% concentration extract with the highest effect compared to the others. Thus, *E. suaveolens* extract has the potential to be an insect control and repellent material for *A. diaperinus* and can potentially be integrated with the chicken house area as a hedge plant.

SIGNIFICANCE STATEMENT

This study identified active compounds from three herbal plants that can be used as bioinsecticides, which can be useful for controlling the insect pest *A. diaperinus*. The toxic and repellent effects of the extracts were used as indicators. The results of this study will help researchers uncover critical areas of these three plants (*E. suaveolens*, *L. camara* and *P. indica*) that remain unexplored by many. As a result, new theories on the insecticidal activity of these plants can be developed.

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