

# Eco-friendly Pest Control Using Organic Materials: Cinnamomum Verum, Garlic and Chili

Nurul Izzah Adnan<sup>1</sup>, Mohammad Arif Budiman Pauzan<sup>1\*</sup> Nurun Najwa Ruslan<sup>1</sup>

<sup>1</sup> Department of Physics and Chemistry, Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Muar, Johor, MALAYSIA

\*Corresponding author: [arifp@uthm.edu.my](mailto:arifp@uthm.edu.my)  
DOI: <https://doi.org/10.30880/jst.2025.17.02.002>

## Article Info

Received: 28 February 2025  
Accepted: 7 November 2025  
Available online: 30 December 2025

## Keywords

Pesticide, essential oil, *Cinnamomum Verum*, chili, garlic

## Abstract

The widespread use of chemical pesticides in agriculture poses environmental risks and health concerns prompting the development of green alternatives from natural sources. This study aims to synthesize a natural pesticide using a mixture of *Cinnamomum Verum* (cinnamon) essential oil, garlic and chili and characterize the functional group of the formulation. The pesticide was prepared by extracting *Cinnamomum Verum* essential oil through distillation and creating garlic and chili solutions by grinding the ingredients with distilled water. The formulation consisted of 25% *Cinnamomum Verum* essential oil (50 mL) mixed with 75% garlic and chili solution (150 mL) in a 1:3 ratio. Active components including eugenol from *Cinnamomum Verum*, capsaicin from chili and allicin from garlic were identified through FTIR analysis confirming potential as natural repellents. The formulated pesticide demonstrates promising pest-repellent properties by effectively reducing pest infestation and leaf damage on chili plants during field evaluations. The synergistic combination of these plant-based bioactive compounds offers a potent, eco-friendly solution for pest control thus contributes to sustainable agricultural practices and safeguarding ecological health.

## 1. Introduction

Pests control, in common name, pesticides significantly impact agriculture and household environments globally which can cause extensive economic damage and serious ecological imbalances [1-4]. Pesticides are classified into several categories based on their target organisms and chemical composition. The primary categories include insecticides, herbicides, fungicides and rodenticides, each designed to manage specific pests or disease in agriculture and vector control [5-6]. Insecticides are specifically designed to control insect populations and encompass categories such as organophosphates, carbamates, pyrethroids and neonicotinoids, each exhibiting unique modes of action and varying potential environmental impacts [7]. Herbicides, employed to manage unwanted vegetation can disrupt ecosystems and adversely affect non-target species [6]. Fungicides target fungal pathogens that impact crop health, thereby contributing to agricultural productivity, yet they also pose risks to human health and the environment [6]. In contrast, biopesticides, which are derived from natural materials including microbial agents and plant extracts, present a more environmentally friendly alternative to synthetic pesticides [6]. While conventional chemical pesticides are effective, substantial environmental and health risks tend to arise and emphasizing the urgent need for sustainable and safe pest control alternatives. Pesticides such as dichlorodiphenyltrichloroethane (DDT), chlordane, aldrin, dieldrin, endrin, heptachlor and hexachlorobenzene have been linked to negative impacts on human health and the environment [1], [8-12]. From 2006 to 2015, Malaysia recorded 11,087 pesticide poisoning cases, with 60% being intentional primarily due to suicide attempts

[4]. Most incidents occurred at home over 90% and the study highlighted an increasing trend in pesticide poisoning incidents [4]. Mosquito control workers in Malaysia were particularly prone to pesticide exposure with the most common route being skin contact referred to as dermal exposure [2]. The research establishes a link between the total amount of pesticide exposure over the lifetime of a worker and negative effects on their neurobehavioral health. The more pesticides these workers were exposed to over time, the more likely they were to experience issues related to cognitive function, motor skills and other aspects of neurobehavioral performance [2]. Given the significant risks posed by chemical pesticides, especially the harmful impacts on health and the environment, exploring safer alternatives was essential. One promising solution involves using essential oils which offer natural pest control properties. For instance, essential oils from plants like *Cinnamomum Verum*, chili and garlic are rich in bioactive compounds that effectively repel pests. Essential oil derived from *Cinnamomum Verum* contains eugenol, a compound that repels insects while capsaicin from chili peppers and allicin from garlic have been recognized for post-repelling capabilities due to its potent antimicrobial properties [13-15]. These active compounds target a variety of pests including aphids, loopers, armyworms, spider mites, thrips and leaf miners [16]. Garlic, rich with the compound allicin which offers health benefits and serves as a natural pesticide. Considering the significance of essential oils in natural pest control, the process of steam distillation is crucial for extracting essential oils from these plants preserving key volatile compounds such as eugenol, capsaicin and allicin which are central to pest-repellent efficacy [17-19]. Thus, this study aims to develop an environmentally friendly pest control formulation by utilizing plant-based extracts. Specifically, extracts from *Cinnamomum Verum*, garlic and chili were prepared through distillation and grinding processes. This study focused on formulating a safe alternative to synthetic pesticides by developing a natural pesticide from selected plant extracts and characterizing its active phytochemicals using FTIR spectroscopy, followed by evaluating its effectiveness in protecting chili plants from pest infestation.

## 2. Methodology

### 2.1 Materials

*Cinnamomum Verum* or *Cinnamomum Verum*, garlic and chili, the primary components of the pesticide formulation were sourced from a local supermarket in Johor, Malaysia.

### 2.2 Experimental Design

To extract the essential oil from *Cinnamomum Verum*, distillation technique was used with distilled water as the solvent. *Cinnamomum Verum* was first washed and dried at 50°C for 24 hours then ground using a pestle and mortar. 25 g of ground *Cinnamomum Verum* was mixed with 400 mL of distilled water and distilled for 2 hours at 100°C. For garlic preparation, 180 g of garlic was washed, chopped and mixed with 300 mL of distilled water then ground using a grinder. The mixture was kept in a warm spot for 24 hours before being filtered to collect the garlic-infused water. The same process was repeated for the chili. The garlic and chili solutions were then mixed until homogeneous. The pesticide was brewed by combining *Cinnamomum Verum* essential oil with the garlic-chili mixture in a 1:3 ratio. The 1:3 ratio of *Cinnamomum Verum* essential oil to the garlic-chili mixture is likely employed to optimize the synergistic effects of the components, enhancing the overall insecticidal efficacy while minimizing potential toxicity [19]. In this study, 50 mL of *Cinnamomum Verum* essential oil was mixed with 150 mL of the garlic-chili solution. The percentage yield of *Cinnamomum Verum* essential oil was also determined after the distillation process. The yield was calculated based on the mass of oil extracted relative to the initial mass of cinnamon powder used in the distillation. The yield was measured after separation and removal of excess moisture using anhydrous sodium sulphate. The percentage yield was calculated using Equation 1. The resulting pesticide was then analyzed for characterization.

$$\text{Percentage yield (\%)} = \frac{\text{Mass of essential oil extracted (g)}}{\text{Mass of } Cinnamomum \text{ Verum powder (g)}}$$

Equation 1

### 2.3 Characterization of Pesticides

#### 2.3.1 Physical Analysis

Physical characteristics of pesticide were observed in their aroma and physical phase at room temperature. The pesticide phase at room temperature was observed through naked eyes and the aroma can be identified through the sense of smell. The color and aroma of pesticide was the result of the *Cinnamomum Verum* essential oil mixed with chili and garlic solution.

### 2.3.2 Active Ingredients Analysis

The phytochemicals of each pesticide compound which was extraction solution from *Cinnamomum Verum*, chili solution and garlic solution have been identified through Fourier Transform Infrared (FTIR) spectroscopy (Thermo Fisher Scientific, USA) by the presence of compound functional groups.

For the methanolic garlic solvent preparation, the garlic bulbs were washed thoroughly to remove any dirt and then chopped into small pieces. Next, the chopped garlic was dried at 60°C for 1 hour. 4 g of dried garlic was added to 30ml of methanol. The mixture was macerated for approximately 30 minutes to allow the extraction of soluble compounds. After maceration, the mixture was filtered using filter paper to remove any solid components, yielding the methanolic garlic solvent. FTIR spectroscopy was used to analyze the methanolic garlic solvent.

For the ethanolic chili solvent preparation, the chili was washed thoroughly to remove any impurities on it. After that, the chili was freed from seeds and chopped into small pieces. The chopped chili was dried at 50°C for 24 hours. Next, the dried chili was grounded into powder form. 4 g of chili powder was weighed and placed in a 150mL beaker with 50 mL 100% ethanol in it. The mixture then was stirred for 30 seconds. After that, the mixture was heated approximately 78°C for 30 minutes. During the heating process, 50mL ethanol was added when the solvent level dropped below 10 mL. Next, the mixture cooled to room temperature, then the liquid extract was separated with a vacuum pump. The filtered extract was transferred to a 50 mL volumetric flask and diluted with distilled water until calibration mark. FTIR spectroscopy was used to analyze ethanolic chili solvent.

### 2.4 Performance Evaluation

Following the preparation and FTIR characterization, the formulated pesticide was tested for the effectiveness in reducing pest activity on chili plants. Two healthy chili plants of similar age and growth stage were selected and placed under similar environmental conditions. One plant was treated with the natural pesticide while the other served as a control (untreated plant). The treated plant was sprayed with the natural pesticide three times daily (morning, afternoon and evening) for a period of four weeks. Observations were carried out weekly to record the number of pests present, the extent of leaf damage, and general plant health (color, leaf turgidity and growth rate). Visual documentation and manual pest counts were used to quantify pest activity.

## 3. Result and Discussion

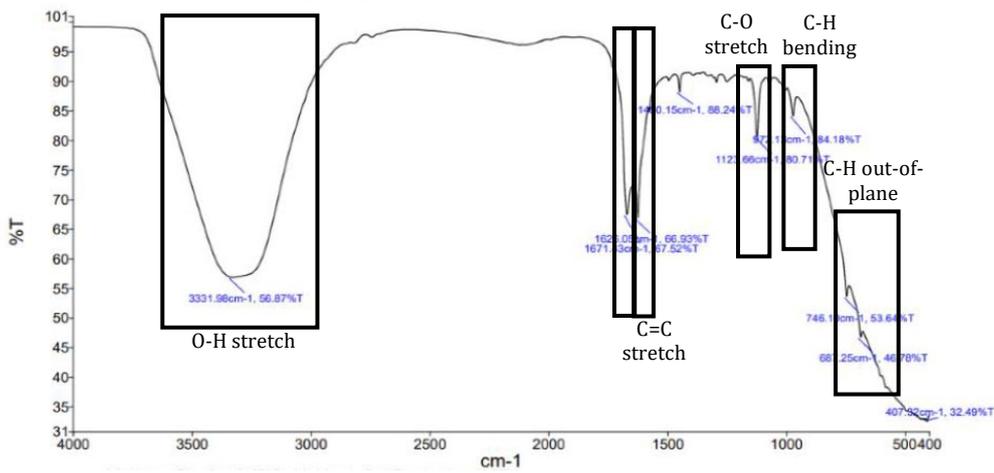
### 3.1 Physical Analysis

The formulated pesticide mixture, composed of *Cinnamomum Verum* essential oil, chili and garlic solutions remains in a liquid state at room temperature. When prepared, the mixture exhibits a characteristic aroma profile: a strong spicy and sweet scent from the *Cinnamomum Verum* essential oil combined with the pungent aroma of chili and garlic. The color of the formulation is observed to be consistent with the natural extracts and the consistency appears homogeneous.

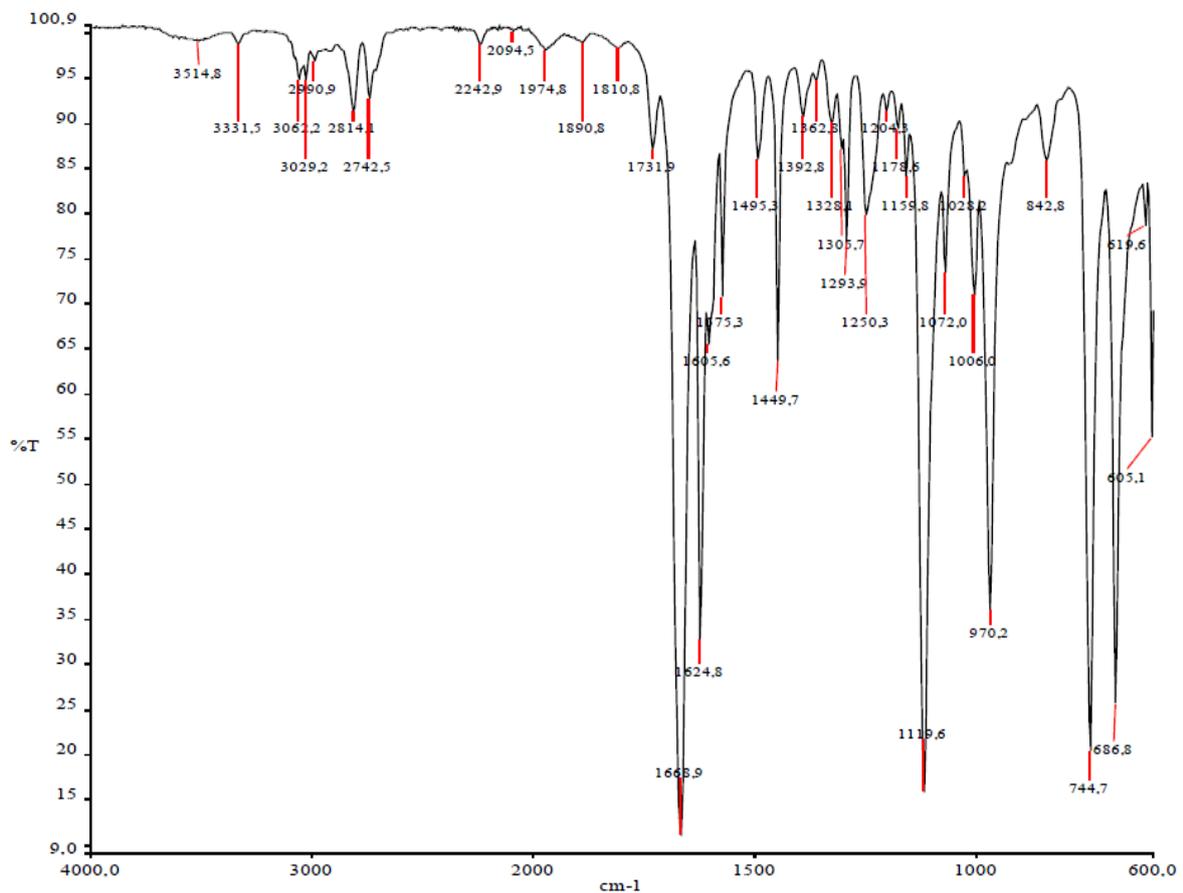
### 3.2 Active Compound Analysis

#### 3.2.1 *Cinnamomum Verum* (Cinnamon) Essential Oil

The FTIR spectrum of *Cinnamomum Verum* essential oil as showed in Fig. 1 reveals several key functional groups that contribute to its potent pesticidal and antimicrobial properties. The broad peak at 3331.96  $\text{cm}^{-1}$ , indicating O-H stretching is typical of alcohols or phenols which are linked to compounds like cinnamaldehyde and eugenol [20]. The strong carbonyl stretching absorption at 1671.43  $\text{cm}^{-1}$  represents C=O stretching, particularly in aldehydes like cinnamaldehyde, which contribute to the potent antimicrobial and insecticidal properties of the oil effects by disrupting cell membranes and interfering with insect metabolism. Additional peaks at 1626.05  $\text{cm}^{-1}$  correspond to C=C stretching in aromatic rings, further supporting the role of these compounds in disrupting biological processes of pests [21] as well as providing herbicidal properties by inhibiting weed growth through disruption of photosynthesis [22], [23]. The peak at 1450.15  $\text{cm}^{-1}$  suggests C-H bending in alkanes or methyl groups, indicating the presence of compounds like eugenol which acts as insecticide by affecting pest nervous systems and leading to paralysis [22]. The peak at 1123.66  $\text{cm}^{-1}$ , corresponding to C-O stretching likely arises from methoxy groups in eugenol [22]. The peaks at 746.10  $\text{cm}^{-1}$  and 687.25  $\text{cm}^{-1}$  are associated with C-H out-of-plane bending in substituted benzene rings contributing to the ability of oil to repel pests by damaging their cellular structures [23]. This comprehensive analysis highlights *Cinnamomum Verum* essential oil as a promising, environmentally friendly alternative to synthetic pesticides due to the synergistic effects of its key functional groups as validated by Boughendjioua et al. (2017) in Fig. 2 [22].



**Fig. 1** FTIR spectra of *Cinnamomum Verum* (*Cinnamomum Verum*) extract



**Fig. 2** FTIR spectra of *Cinnamomum Verum* (cinnamon) essential oil [22]

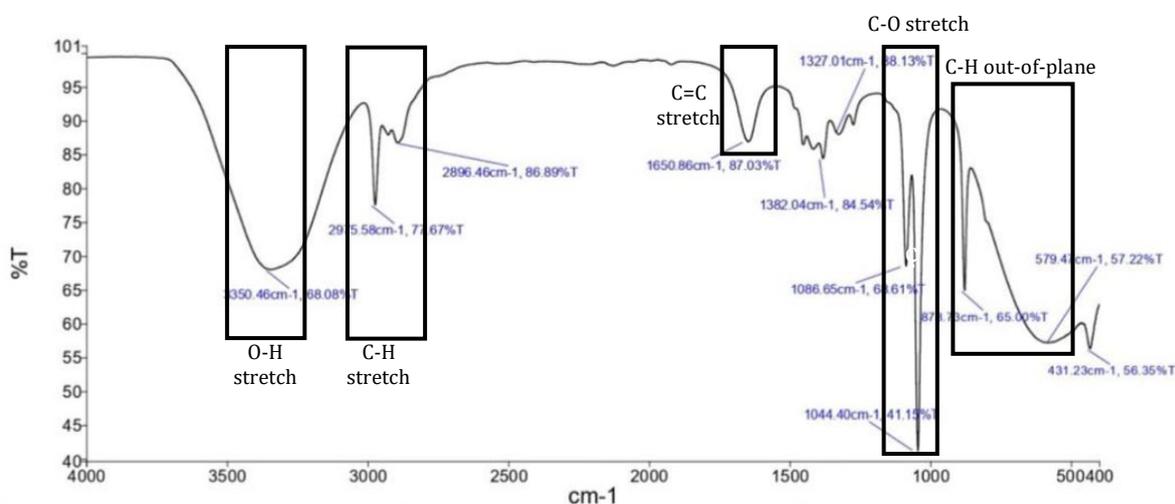
The average essential oil yield obtained was  $5.40 \pm 0.23\%$  as shown in Table 1. The obtained yield reflects an efficient extraction process, ensuring adequate recovery of volatile compounds responsible for the pesticide's biological activity. The moderate yield (5.40%) indicates effective distillation without significant thermal degradation of key constituents, as confirmed through FTIR analysis which identified characteristic functional groups of aldehydes, phenols, and aromatic hydrocarbons. Higher yield of *Cinnamomum verum* essential oil directly correlates with greater concentration of bioactive compounds thus enhancing the pesticidal effectiveness when blended with garlic and chili extracts.

**Table 1** Percentage yield of *Cinnamomum Verum* essential oil

Sample ID	Mass of <i>Cinnamomum Verum</i> Powder (g)	Mass of Essential Oil Extracted (g)	Yield
S1	25	1.35	5.40
S2	25	1.28	5.12
S3	25	1.42	5.68
Average			5.40 ± 0.23

### 3.2.2 Chili

FTIR spectra and characteristics peaks of in chili were presented in Fig. 3. The peak at 3350.46 cm<sup>-1</sup> shows O-H stretching, commonly associated with alcohols or phenols which may reflect the presence of compounds such as capsaicin known for its strong antimicrobial and pest-repellent activities [24]. The C-H stretching vibrations at 2975.58 cm<sup>-1</sup> and 2896.46 cm<sup>-1</sup> suggest alkanes which contribute to the structural integrity and potential repellent properties of the extract [20], [24]. The C=C stretching seen at 1650.86 cm<sup>-1</sup> identifies aromatic rings potentially indicating phenolic compounds that disrupt metabolic processes in pests [20], [24]. Additionally, C-O stretching vibrations at 1086.65 cm<sup>-1</sup> and 1044.40 cm<sup>-1</sup> are indicative of ethers or esters which important for in influencing pest behavior and mortality [20], [22], [23], [24]. The C-H out-of-plane bending at 878.73 cm<sup>-1</sup> and 579.47 cm<sup>-1</sup>, and the peak at 431.23 cm<sup>-1</sup>, may also contribute to the overall pesticidal efficacy of the chili extract by affecting cellular structures in pests [22], [24].

**Fig. 3** FTIR spectra of chili extract

### 3.2.3 Garlic

Fig. 4 showed the FTIR spectra of allicin in garlic liquid after the extraction process. The broad peak at 3326.00 cm<sup>-1</sup> indicates O-H stretching from alcohols or phenols, likely associated with organosulfur compounds such as allicin known for their antimicrobial effects [25]. Peaks at 2944.95 cm<sup>-1</sup> and 2834.27 cm<sup>-1</sup> correspond to C-H stretching in alkanes, while C=O stretching at 1651.18 cm<sup>-1</sup> suggests the presence of amides or carbonyl compounds contributing to its bioactivity [25]. The peaks at 1449.33 cm<sup>-1</sup> and 1411.90 cm<sup>-1</sup> indicate C-H bending, and C-O stretching at 1113.67 cm<sup>-1</sup> points to oxygenated compounds, potentially from sulfides [25]. Lastly, the C-S stretching peaks at 1019.11 cm<sup>-1</sup> and 590.81 cm<sup>-1</sup> represent sulfur-containing compounds like allicin and diallyl disulfide [25], which are crucial for disrupting pest metabolic processes. Together, these functional groups make garlic extract an effective natural pesticide.

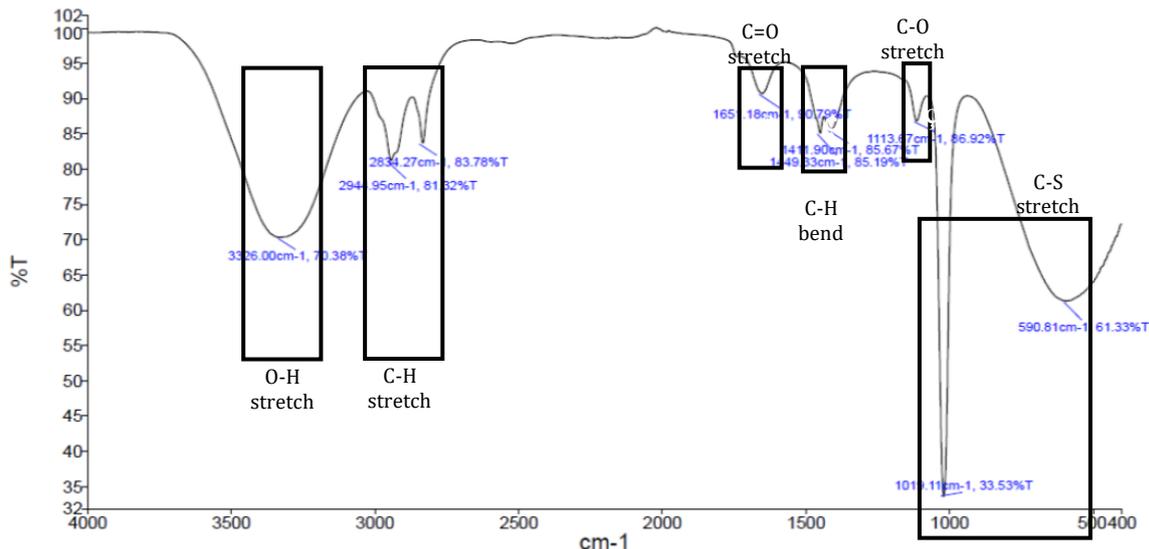


Fig. 4 FTIR spectra of garlic extract

The FTIR spectra of *Cinnamomum Verum*, chili and garlic extracts highlight several key functional groups that contribute to their pesticidal properties. All extracts show O-H stretching peaks indicating the presence of alcohols or phenols, which are linked to antimicrobial and insecticidal activity. C-H stretching peaks in all spectra suggest alkanes, contributing to structural stability and biological activity. The C=C stretching in the aromatic rings, particularly in *Cinnamomum Verum* and chili extracts, occurs around 1650 cm<sup>-1</sup> and is crucial for disrupting pest metabolic functions. Garlic's spectrum shows a strong C=O indicating the presence of carbonyl groups, which enhance its pesticidal effects. C-O stretching is evident in all spectra, particularly around 1000–1100 cm<sup>-1</sup> which corresponds to oxygenated compounds, such as ethers or sulfides, important in garlic and eugenol-rich *Cinnamomum Verum* extracts. Additionally, C-S stretching in garlic's spectrum reveals the presence of sulfur-containing compounds like allicin, which are particularly potent in disrupting pest enzymatic systems. These compounds act synergistically, cinnamaldehyde from cinnamon disrupts pest cell membranes and respiration, allicin from garlic inhibits enzyme function and capsaicin from chili repels insects by interfering with neural pathways.

### 3.3 Performance Evaluation of Formulated Natural Pesticide on Chili Plants

The formulated natural pesticide composed of *Cinnamomum verum* essential oil, chili and garlic extracts was evaluated for the ability to reduce pest infestation and leaf damage on chili plants under ambient conditions. Two healthy chili plants of similar size and age were selected, one treated with the formulated pesticide and one left untreated as a control. The treated plant was sprayed with the natural pesticide three times daily (morning, afternoon, and evening) for four consecutive weeks. Weekly observations were made as recorded in Table 2 and as showed in Fig. 5, Fig. 6 and Fig. 7 to evaluate the number of visible pests per ten leaves, percentage of leaf area damaged as well as the overall plant health condition.

Table 2 Weekly observation of pest activities and plant condition for treated and untreated chili plants

Week	Treatment	Average Pest (per 10 leaves)	Leaf Damage (%)	Plant Health Description
1	Untreated (Control)	0	0	Healthy with no visible pest activity. Leaves were fully green and turgid.
1	Treated (Pesticide)	0	0	Same condition as control. No visible pests or damage observed.
2	Untreated (Control)	12	18%	Early signs of aphid and leaf-miner presence on lower leaves. Slight curling and minor yellowing observed.
2	Treated (Pesticide)	0	0	Leaves remained shiny and green. No pests detected.

Week	Treatment	Average Pest (per 10 leaves)	Leaf Damage (%)	Plant Health Description
3	Untreated (Control)	18	28%	Noticeable increase in pest colonies and small holes on several leaves. Plant growth slowed and leaves showed curling edges.
3	Treated (Pesticide)	0	0	Plant remained pest-free. Leaf surface remained smooth and bright green with vigorous growth.
4	Untreated (Control)	25	40%	Over half of lower leaves wilted and yellowed.
4	Treated (Pesticide)	0	0	No visible pest presence throughout the observation. The plant showed healthy branching, strong leaf turgor and continuous new leaf formation.



(a)



(b)

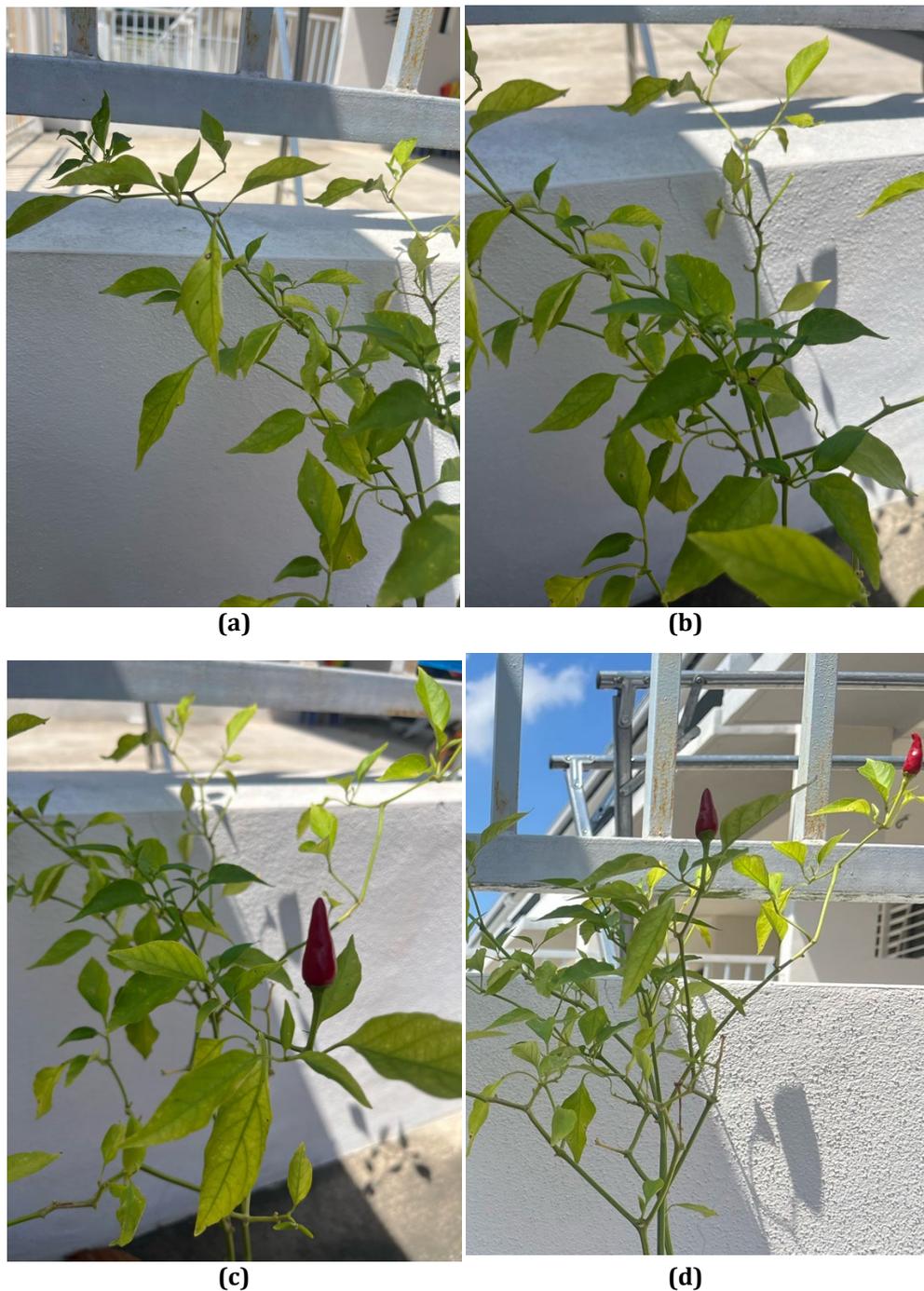


(c)



(d)

**Fig. 5** Progression of pest infestation and leaf health on untreated chili plants throughout (a) Week 1; (b) Week 2; (c) Week 3; and (d) Week 4



**Fig. 6** Progression of pest infestation and leaf health on treated chili plants throughout (a) Week 1; (b) Week 2; (c) Week 3; and (d) Week 4

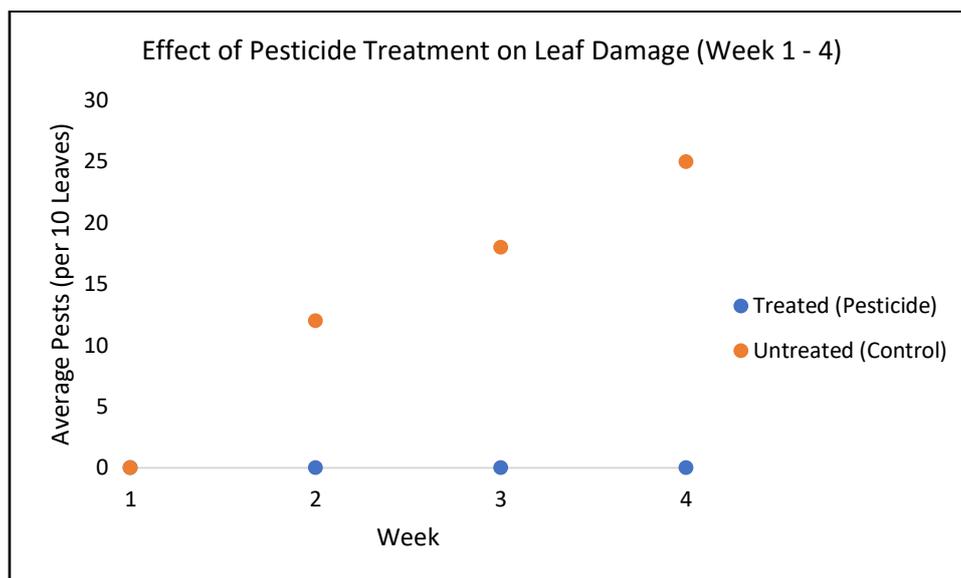


Fig. 7 Effect of pesticide treatment on leaf damage (week 1-4) line chart

The observation clearly demonstrates the effectiveness of the formulated natural pesticide in preventing pest colonization and maintaining leaf integrity. The untreated (control) plant experienced a progressive increase in pest population from Week 2 onward reaching 25 pests per 10 leaves by Week 4. Leaf damage correspondingly rose from 18% in Week 2 to 40% in Week 4. In contrast, the treated plant consistently showed zero infestation and zero visible leaf damage throughout the four-week period. The absence of pest activity suggests that the formulation provided a strong repellent barrier immediately after application and sustained protection across the entire observation period.

Indeed, the essential oil that was mixed in a 1:3 ratio with garlic-chili solution (50 mL oil : 150 mL aqueous extract) successfully balanced potency and minimized phytotoxicity on plant leaves. The yield obtained was sufficient to maintain a consistent formulation that exhibited complete pest suppression throughout the four-week observation. A higher yield would potentially increase bioactivity but could also lead to over-concentration, resulting in leaf burn or phytotoxic symptoms due to the high volatility of cinnamaldehyde. Conversely, lower yields could reduce insecticidal effectiveness by weakening the concentration of active compounds. Hence, maintaining a moderate and reproducible yield (around 5%) ensures the best balance between effectiveness and safety for field application.

#### 4. Conclusion

In summary, FTIR spectroscopy of the *Cinnamomum Verum*, chili and garlic extracts revealed the presence of key functional groups such as hydroxyl, carbonyl, aromatic and sulfur-containing groups that are associated with various bioactive and pesticidal properties. The study also demonstrated that the formulated natural pesticide effectively protected chili plants from pest infestation over a four-week period. The untreated control plant experienced rapid pest colonization leading to approximately 40% leaf damage within the same timeframe. In contrast, the treated plant remained entirely pest-free and exhibited vigorous growth and healthy development throughout the observation period. The application of the natural pesticide showed strong repellency without any phytotoxic effects on the chili plants confirming its safety and suitability for use. The synergistic action of *Cinnamomum Verum* essential oil, chili and garlic extracts underscores the potential of this environmentally friendly pest-control strategy as a sustainable alternative to synthetic pesticides, promoting enhanced plant health with minimal ecological impact.

#### Acknowledgement

The authors would also like to thank Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia for providing the facilities and resources necessary to conduct this research.

#### Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

## Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Nurul Izzah Adnan, Mohammad Arif Budiman Pauzan; **data collection:** Nurul Izzah Adnan; **analysis and interpretation of results:** Nurul Izzah Adnan, Mohammad Arif Budiman Pauzan, Nurun Najwa Ruslan; **draft manuscript preparation:** Nurul Izzah Adnan, Mohammad Arif Budiman Pauzan; All authors reviewed the results and approved the final version of the manuscript.

## References

- [1] Types, Names and Formulations What are Pesticides?," 2017.
- [2] M. Z. Yusof, J. W. Cherrie, N. Samsuddin, and S. Semple, "Mosquito Control Workers in Malaysia: Is Lifetime Occupational Pesticide Exposure Associated With Poorer Neurobehavioral Performance?," *Ann Work Expo Health*, vol. 66, no. 8, pp. 1044–1055, Oct. 2022, doi: 10.1093/annweh/wxac038.
- [3] N. A. Kamaruzaman *et al.*, "Epidemiology and risk factors of pesticide poisoning in Malaysia: a retrospective analysis by the National Poison Centre (NPC) from 2006 to 2015," *BMJ Open*, vol. 10, no. 6, p. e036048, Jun. 2020, doi: 10.1136/bmjopen-2019-036048.
- [4] L. F. Chan *et al.*, "Surveillance of pesticide poisoning in an East and a West Malaysian hospital: characteristics of pesticide poisoning and the early impact of a national Paraquat ban," *BMC Psychiatry*, vol. 23, no. 1, p. 472, Jun. 2023, doi: 10.1186/s12888-023-04974-8.
- [5] C. J. Karr and V. A. Rauh, "Pesticides," in *Textbook of Children's Environmental Health*, Oxford University Press New York, 2024, pp. 466–476. doi: 10.1093/oso/9780197662526.003.0035.
- [6] R. Deolikar *et al.*, "Pesticides: Types, Toxicity and Recent Updates on Bioremediation Strategies," 2021, pp. 531–568. doi: 10.1007/978-3-030-63422-3\_27.
- [7] M. F. Araújo, E. M. S. Castanheira, and S. F. Sousa, "The Buzz on Insecticides: A Review of Uses, Molecular Structures, Targets, Adverse Effects, and Alternatives," *Molecules*, vol. 28, no. 8, p. 3641, Apr. 2023, doi: 10.3390/molecules28083641.
- [8] A. Sharma *et al.*, "Worldwide pesticide usage and its impacts on ecosystem," *SN Appl Sci*, vol. 1, no. 11, p. 1446, Nov. 2019, doi: 10.1007/s42452-019-1485-1.
- [9] W. Guo *et al.*, "Persistent Organic Pollutants in Food: Contamination Sources, Health Effects and Detection Methods," *Int J Environ Res Public Health*, vol. 16, no. 22, p. 4361, Nov. 2019, doi: 10.3390/ijerph16224361.
- [10] S. Ozen, D. Goksen, and S. Darcan, "Agricultural Pesticides and Precocious Puberty," 2014, pp. 27–40. doi: 10.1016/B978-0-12-800095-3.00002-X.
- [11] C. Costa *et al.*, "New perspectives on cytokine pathways modulation by pesticide exposure," *Curr Opin Toxicol*, vol. 19, pp. 99–104, Feb. 2020, doi: 10.1016/j.cotox.2020.01.002.
- [12] R. Jayaraj, P. Megha, and P. Sreedev, "Review Article. Organochlorine pesticides, their toxic effects on living organisms and their fate in the environment," *Interdiscip Toxicol*, vol. 9, no. 3–4, pp. 90–100, Dec. 2016, doi: 10.1515/intox-2016-0012.
- [13] J.-L. Ríos, "Essential Oils," in *Essential Oils in Food Preservation, Flavor and Safety*, Elsevier, 2016, pp. 3–10. doi: 10.1016/B978-0-12-416641-7.00001-8.
- [14] R. Ribeiro-Santos *et al.*, "Revisiting an ancient spice with medicinal purposes: Cinnamon," *Trends Food Sci Technol*, vol. 62, pp. 154–169, Apr. 2017, doi: 10.1016/j.tifs.2017.02.011.
- [15] P. Mikaili, S. Maadirad, M. Moloudizargari, S. Aghajanshakeri, and S. Sarahroodi, "Therapeutic uses and pharmacological properties of garlic, shallot, and their biologically active compounds.," *Iran J Basic Med Sci*, vol. 16, no. 10, pp. 1031–48, Oct. 2013.
- [16] J. Dougoud, S. Toepfer, M. Bateman, and W. H. Jenner, "Efficacy of homemade botanical insecticides based on traditional knowledge. A review," *Agron Sustain Dev*, vol. 39, no. 4, p. 37, Aug. 2019, doi: 10.1007/s13593-019-0583-1.
- [17] E. Cassel, R. M. F. Vargas, N. Martinez, D. Lorenzo, and E. Dellacassa, "Steam distillation modeling for essential oil extraction process," *Ind Crops Prod*, vol. 29, no. 1, pp. 171–176, Jan. 2009, doi: 10.1016/j.indcrop.2008.04.017.
- [18] M. G. Cerpa, R. B. Mato, and M. José Cocero, "Modeling steam distillation of essential oils: Application to lavandin super oil," *AIChE Journal*, vol. 54, no. 4, pp. 909–917, Apr. 2008, doi: 10.1002/aic.11438.
- [19] P. Masango, "Cleaner production of essential oils by steam distillation," *J Clean Prod*, vol. 13, no. 8, pp. 833–839, Jun. 2005, doi: 10.1016/j.jclepro.2004.02.039.

- [20] V. Jha *et al.*, "Chemical Composition, Bioactive Potential, and Thermal Behaviour of *Cyperus scariosus* Essential Oil," *Chemical Science International Journal*, pp. 1–14, Jun. 2022, doi: 10.9734/CSJI/2022/v3i1230276.
- [21] H. Chen *et al.*, "Synthesis of mesoporous silica post-loaded by methyl eugenol as an environment-friendly slow-release bio pesticide," *Sci Rep*, vol. 10, no. 1, p. 6108, Apr. 2020, doi: 10.1038/s41598-020-63015-6.
- [22] H. Boughendjioua, N. Amoura, and Z. Boughendjioua, "Department of Natural Sciences, High School Professors Technological Education, Skikda, 21000, Algeria 36," Hicham Boughendjioua, 2017. [Online]. Available: [www.ijpbr.in](http://www.ijpbr.in)
- [23] B. Jiang, J. Song, and Y. Jin, "A flavonoid monomer triclin in Gramineous plants: Metabolism, bio/chemosynthesis, biological properties, and toxicology," *Food Chem*, vol. 320, p. 126617, Aug. 2020, doi: 10.1016/j.foodchem.2020.126617.
- [24] B. Jing, W. Song, X. Gao, K. He, Q. Sun, and X. Tang, "A feasibility quantification study of capsaicin content in chili powder for rapid evaluation using near-infrared reflectance spectroscopy," *Journal of Food Measurement and Characterization*, vol. 17, no. 5, pp. 4405–4414, Oct. 2023, doi: 10.1007/s11694-023-01965-x.
- [25] L. A. da S. Alvarino, F. Manzotti, W. M. Moreira, T. P. de Araújo, D. T. Vareschini, and M. A. S. D. de Barros, "Antibacterial Potential of Activated Carbon Impregnated with Garlic Extract," *Processes*, vol. 11, no. 10, p. 2948, Oct. 2023, doi: 10.3390/pr11102948.