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Research Article

The Effect of Clove Leaves (*Syzygium aromaticum* L.) on Controlling the Maize Weevil (*Sitophilus zeamais*) Infestation in Stored Maize Seeds

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Abstract
Storage is a crucial post-harvest handling process; however, during storage, agricultural products are susceptible to various types of deterioration. Post-harvest losses reach approximately 15–20% annually, with about 0.5–2% of those losses caused by the maize weevil (*Sitophilus zeamais*). Clove leaves, which produce a characteristic aroma, contain an essential oil component called eugenol, known for its fungicidal, bactericidal, nematicidal, and insecticidal properties. This study aimed to determine the effectiveness and optimal weight of clove leaves (*Syzygium aromaticum L.*) in controlling *Sitophilus zeamais*. The research employed a Completely Randomized Design (CRD) consisting of five treatments and three replications. The treatments included: K1 = 0 g (control, without clove leaves); K2 = 10 g clove leaves per 100 g maize; K3 = 30 g clove leaves per 100 g maize; K4 = 50 g clove leaves per 100 g maize; and K5 = 70 g clove leaves per 100 g maize. Observations were conducted once for each replicate, resulting in three data points per treatment. The collected data were analyzed using ANOVA. The results indicated that clove leaves can be used to control maize weevil (*Sitophilus zeamais M.*) infestations in stored maize. A total clove leaf weight of 70 g resulted in the highest mortality rate, with 9.08 individuals, yet this treatment was still not considered effective as it did not achieve more than 80% mortality of *Sitophilus zeamais*.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most widely cultivated cereal crops, serving as a vital source of food, animal feed, and industrial raw materials. It is rich in carbohydrates and proteins, and also contains essential vitamins such as A, B, and E, as well as various minerals (Wulandari & Batoro, 2016; Fiqriansyah *et al*., 2021). According to Saputro *et al*. (2023), maize consumption in Indonesia has steadily increased over the years, driven by rising per capita consumption and population growth. Data from the Central Bureau of Statistics (2016) indicate that maize production reached 28,052 tons in 2013, 28,651 tons in 2014, and 30,870 tons of dry shelled maize in 2015 (Rustam & Audina, 2018).

Storage is a crucial component of post-harvest management; however, during storage, agricultural products are highly susceptible to various forms of deterioration (Manandhar *et al*., 2018; Molenaar, 2020; Tahir, 2023). This deterioration may be physical, chemical, mechanical, biological, or microbiological in nature (Arini, 2017). According to Nonci and Muis (2015), post-harvest losses can reach 15–20% annually, with 0.5–2% attributed specifically to infestation by the maize weevil (*Sitophilus zeamais*). Wagiman (2019) also reported that storage pests can account for 26–29% of total losses in warehouse-stored agricultural products. *S. zeamais* is a polyphagous pest capable of infesting not only maize but also rice, legumes, cassava chips, copra, and other stored grains (Saenong, 2016; Nuraini *et al*., 2022).

Farmers typically rely on synthetic insecticides to manage post-harvest pests, either through direct spraying or fumigation (Stejskal *et al*., 2021; Thakur *et al*., 2021; Berhe *et al*., 2022). However, over time, this method has revealed several drawbacks, including residual toxicity in food products, negative environmental impacts, and the development of pest resistance (Ali *et al*., 2020; Yigit & Velioglu, 2020). Consequently, there is a growing need for alternative pest control methods, such as botanical insecticides.

Botanical insecticides are derived from plant secondary metabolites that exert one or more biological effects on pests, influencing either their physiological functions or behavioral responses, and are considered environmentally safer options for pest management (Hikal *et al*., 2017; Ukoroije & Otayor, 2020; Senthil-Nathan, 2020). Various plant species contain chemical compounds with insecticidal properties, one of which is clove (*Syzygium aromaticum*).

Clove is an important spice crop, with its most commercially valuable part being the flower buds, which are primarily used in the cigarette industry (80–90%) (Sari *et al*., 2020; Pio, 2025). However, clove leaves remain underutilized and are often treated as waste. These leaves contain essential oils rich in eugenol, a compound responsible for their characteristic aroma (Martias & Ajadit, 2020; Viqri *et al*., 2024). Numerous studies have demonstrated that eugenol possesses fungicidal, bactericidal, nematicidal, and insecticidal properties (Saenong, 2016; Gustina *et al*., 2021; Laila, 2025). In addition to pest control, clove plants are widely used in the pharmaceutical and fragrance industries (in formulations with geranium, bergamot, caraway, cassie, and soap perfumes) (Sasongko *et al*., 2022; Herdiana *et al*., 2024).

The objective of this study was to evaluate the effectiveness of clove application and the optimal dosage required to control *Sitophilus zeamais* infestations in stored maize.

RESEARCH METHODS

Type of Research

This study was a laboratory-based experimental research.

Experimental Design

The study employed a Completely Randomized Design (CRD) with five treatment levels representing different weights of clove leaves: 0 g (control), 10 g, 30 g, 50 g, and 70 g. Each treatment was replicated three times, resulting in a total of 15 experimental units. The treatments were defined as follows:

- K1 = 0 g (Control; no clove leaves)
- K2 = 10 g clove leaves mixed with 100 g maize
- K3 = 30 g clove leaves mixed with 100 g maize
- K4 = 50 g clove leaves mixed with 100 g maize
- K5 = 70 g clove leaves mixed with 100 g maize

Tools and Materials

The tools used in this study included jars, label paper, rubber bands, muslin cloth, a digital scale, a digital camera, a magnifying glass, and stationery. Materials used were adult *Sitophilus zeamais* (imago), mature clove leaves (dark green in color), and maize kernels, which served as feed for *S. zeamais*.

Research Procedures

Clove Leaf Collection

The clove leaves used in this study were mature (dark green) and collected from the base of the clove tree in the Ama Ory Hamlet, Passo Village, Ambon City. A total of 195 g of leaves (approximately five leaves per tree) were collected, washed with clean water, and air-dried at room temperature.

Maize Preparation

The maize used in the experiment was obtained from a storage facility at Mardika Market, Ambon City.

Test Insect Rearing

a. Adult *Sitophilus zeamais* were collected from infested maize in storage areas and brought to the laboratory.

b. The collected insects were placed in jars measuring 30 cm in height and 20 cm in diameter, each containing 1 kg of cleaned maize as both feed and a breeding medium. The jars were covered with muslin cloth secured with rubber bands and maintained for four weeks to allow reproduction (Sarbunan, 2015).

c. To ensure uniform insect age at the time of testing, second-generation *S. zeamais* adults were used. A total of 300 individuals were required for the experiment (15 experimental units × 20 insects per unit).

Pest Activity Testing

a. A total of 15 jars (15 cm height, 10 cm diameter) were each filled with 20 adult *S. zeamais*.

b. Each jar also contained 100 g of maize and a specific amount of bruised clove leaves (according to treatment). The jars were then covered with muslin cloth and secured with rubber bands.

c. Observations were conducted over a 3-day period. Timing began immediately after the insects were introduced into the containers.

Mortality Observation

Insect mortality was observed by counting the number of dead adult *S. zeamais* after the treatment period. Observations were conducted once for each replicate, resulting in three observations per treatment. The percentage of mortality was calculated using the formula:

$$P = \frac{a}{a+b} \times 100\%$$

Where:

P = mortality percentage of *S. Zeamais*
a = number of dead insects

b = number of live insects

Data Analysis

To evaluate the effect of clove leaf application on *S. zeamais* mortality, the data were analyzed using one-way Analysis of Variance (ANOVA) at a 95% confidence level (Moniharapon *et al*., 2020; Kaihena & Ukratalo, 2021; Moniharapon & Ukratalo, 2021). When significant differences were found among treatments, the results were further analyzed using the Least Significant Difference (LSD) test.

RESULTS AND DISCUSSION

Observations on the mortality of maize weevils (*Sitophilus zeamais*) in maize seeds over 4 day following the application of clove leaves are presented in Table 1

Table 1. Mortality rate of maize weevil in maize seeds during the observation period

Treatment	Mean Total Mortality± SD				Total
	Day 1	Day 2	Day 3	Day 4	
Control	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	**0,00±0,00[a]**
10 g	0,33±0,58	1,33 ±1,53	3,33±2,31	5,33±3,06	**2,58±2,68[b]**
30 g	1,33±0,58	3,33±0,58	4,33±1,53	6,33±1,53	**3,83±2,13[b]**
50 g	4,00±1,00	5,67±2,08	7,67±2,89	10,33±4,16	**6,92±3,42[c]**
70 g	4,33±3,21	6,67±3,22	10,67±4,51	14,67±5,03	**9,08±5,41[d]**
Total Mean	**2,00±2,30[a]**	**3,40±3,09[a]**	**5,20±4,43[a]**	**7,33±2,82[b]**	

Note: Superscripts with the same letter indicate no significant difference (P > 0.05).

The results presented in Table 1 indicate that the highest average mortality of *Sitophilus zeamais* was observed in the treatment with 70 g of clove leaves, with a mean of 9.08 ± 5.41 individuals over the 4-day observation period. Conversely, the lowest mortality was recorded in the control group (0 g), with no insect mortality (0.00 ± 0.00). Additionally, observation time significantly influenced the average mortality rate. On Day 1, the mean mortality was 2.00 ± 2.30, increasing progressively to 7.33 ± 2.82 on Day 4. This suggests that the insecticidal activity of clove leaves increased with time, likely due to the sustained release and exposure to volatile compounds, such as eugenol, present in the leaves.

The mortality trends of *S. zeamais* in response to clove leaf treatments across the observation period are further illustrated in Figure 1.

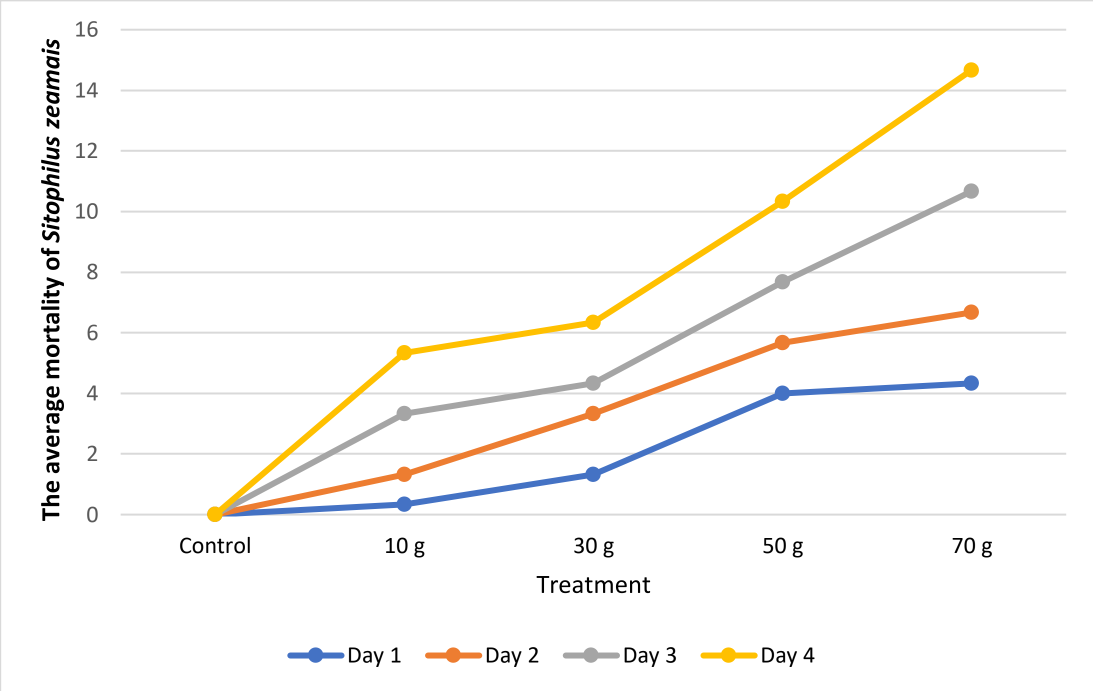

Figure 1. Graph of average mortality rate of *Sitophilus zeamais* following clove leaf treatment

Based on the data presented in Figure 1, it can be observed that the higher the weight of clove leaves applied, the greater the mortality of *Sitophilus zeamais*. This phenomenon occurs because an increase in the weight of clove leaves corresponds to a higher concentration of active compounds, which contribute to the mortality of *S. zeamais*. A high level of toxicity leads to a more rapid mortality rate in *S. zeamais* (Faqy & Rustam, 2019). Rustam and Tarigan (2021) also stated that the dosage level significantly influences the concentration of active ingredients and affects the time required to induce insect mortality.

Clove leaves contain essential oils, primarily eugenol (Tahir *et al*., 2019; Tahir *et al*., 2020). The eugenol compound in clove leaves acts as a fumigant toxin, which interferes with the nervous system and leads to the death of *S. zeamais* beetles (Faqy & Rustam, 2019). According to Wahab (2021), eugenol inhibits the function of the enzyme acetylcholinesterase, which hydrolyzes acetylcholine, a neurotransmitter responsible for transmitting nerve impulses. Acetylcholine is normally broken down into choline and acetic acid with the help of acetylcholinesterase (Reubun *et al*., 2020). When the activity of acetylcholinesterase is inhibited, acetylcholine accumulates, causing symptoms such as tremors, convulsions, and paralysis, which eventually result in mortality (Faqy & Rustam, 2019). Rustam and Audina (2018) reported that the initial signs of mortality in *S. zeamais* are characterized by a noticeable decrease in the movement of active adult beetles several days after treatment with noni seed flour. Dead individuals are identified by drooping antennae and legs curled inward.

In the present study, the average mortality of *S. zeamais* on day 1 remained relatively low. At a leaf weight of 10 g, mortality was recorded at 0.33 individuals; 30 g resulted in 1.33 individuals; 50 g caused 4.00 individuals; and 70 g yielded 4.33 individuals. This may be attributed to the rapid degradation of eugenol, the active compound in clove leaves. This finding aligns with who noted that one of the limitations of botanical insecticides is their low toxicity. Moreover, eugenol belongs to the phenol group, which is highly volatile.

The highest average mortality of *S. zeamais* was observed at the clove leaf weight of 70 g. This is likely due to the increased toxicity at this weight, which accelerates mortality. In addition, the increased mortality observed on day 4 is likely due to the insects' initial tolerance of the toxin during the early exposure period (day 1–2), allowing them to survive temporarily. This observation is in agreement with Sembel (2015), who stated that every organism possesses a threshold of tolerance to toxins below which mortality does not occur. The sensitivity of an insect to bioactive compounds is influenced by its metabolic ability to detoxify and eliminate toxins from its body (Nur *et al*., 2024; Chamani *et al*., 2025).

Overall, the total mortality observed in this study was relatively low compared to the findings of Faqy and Rustam (2019), who reported that clove flower powder used as a fumigant achieved 92.50% mortality against *Callosobruchus maculatus* F. This discrepancy may be due to the rapid volatilization of eugenol in clove leaves, resulting in minimal inhalation of the active compound by *S. zeamais*. Therefore, a clove leaf weight of 70 g is not yet considered effective as a botanical fumigant pesticide. This conclusion is supported by Azhari (2022), who stated that a botanical pesticide is considered effective if the treatment results in insect mortality exceeding 80%.

The results of the ANOVA indicated that the F-values for both treatment and observation time were less than 0.05 ($p < 0.05$), suggesting that the application of clove leaves (*Syzygium aromaticum* L.) and the duration of observation significantly affected the average mortality of *Sitophilus zeamais*.

The Least Significant Difference (LSD) test further revealed that the mean mortality rates of *S. zeamais* for the control, 50 g, and 70 g treatments were significantly different from each other. However, no significant difference was observed between the 10 g and 30 g treatments. In terms of observation time, no significant difference in mortality was found on days 1, 2, and 3, whereas a significant difference was observed on day 4.

CONCLUSION

Clove leaves can be used to control maize weevil (*Sitophilus zeamais* M.) infestations in stored corn. The treatment with 70 g of clove leaves resulted in the highest mortality rate, reaching 9.08 individuals. However, this level of mortality is still considered ineffective for controlling *S. zeamais*, as it does not exceed the threshold of 80% mortality required for a botanical pesticide to be deemed effective.

DECLARATIONS

Author Contributions

K. N. T contributed to designing the study, preparing samples and test materials, conducting the study, and preparing the manuscript. D. D. M contributed to proofreading the manuscript.

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Declaration of Interest

The authors declare no relevant conflicts of interest related to this study.

Data Sharing Statement

The data used in this are available upon reasonable request and in accordance with established procedures.

REFERENCE

Ali, S., Ullah, M. I., Sajjad, A., Shakeel, Q., & Hussain, A. (2020). Environmental and health effects of pesticide residues. In *Sustainable agriculture reviews 48: Pesticide occurrence, analysis and remediation vol. 2 analysis* (pp. 311-336). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-54719-6_8

Arini, L. D. D. (2017). Faktor-faktor penyebab dan karakteristik makanan kadaluarsa yang berdampak buruk pada kesehatan masyarakat. *JITIPARI (Jurnal Ilmiah Teknologi dan Industri Pangan UNISRI)*, *2*(1).

Azhari, D., Sudirman, A., & Maryanti, M. (2022). Uji Efektivitas Pestisida Nabati Ekstrak Daun Pepaya (*Carica papaya* L.) dan Ekstrak Ubi Gadung (*Dioscorea hispida* Dennst) pada Mortalitas Penghisap Buah Kakao (*Helopeltis* spp.). *Jurnal Agro Industri Perkebunan*, 97-104. https://doi.org/10.25181/jaip.v10i2.2283

Berhe, M., Subramanyam, B., Chichaybelu, M., Demissie, G., Abay, F., & Harvey, J. (2022). Post-harvest insect pests and their management practices for major food and export crops in East Africa: An Ethiopian case study. *Insects*, *13*(11), 1068. https://doi.org/10.3390/insects13111068

Chamani, M., Dadpour, M., Dehghanian, Z., Panahirad, S., Chenari Bouket, A., Oszako, T., & Kumar, S. (2025). From Digestion to Detoxification: Exploring Plant Metabolite Impacts on Insect Enzyme Systems for Enhanced Pest Control. *Insects*, *16*(4), 392. https://doi.org/10.3390/insects16040392

Faqy, R. C., & Rustam, R. (2019). Uji beberapa konsentrasi tepung bunga cengkeh (*Syzygium aromaticum* (L.) Merr. dan Perry) untuk mengendalikan hama *Sitophilus zeamais* M. pada biji jagung di penyimpanan. In *Unri Conference Series: Agriculture and Food Security* (Vol. 1, pp. 67-77). https://doi.org/10.31258/unricsagr.1a9

Fiqriansyah, W., Syam, R., & Rahmadani, A. (2021). Teknologi budidaya tanaman jagung (*Zea mays*) dan sorgum (*Sorghum bicolor* (L.) Moench).

Gustina, M., Ali, H., & Kurniawan, Y. (2021). Efektivitas Ekstrak Daun Cengkeh (*Syzigium aromaticum*) Dalam Mematikan Lalat Rumah (*Musca domestica*). *Journal of Nursing and Public Health*, *9*(1), 61-68. https://doi.org/10.37676/jnph.v9i1.1442

Herdiana, N., Sugiharto, R., & Winanti, D. D. T. (2024). *Rempah Dan Minyak Atsiri Daun*. CV. Gita Lentera.

Hikal, W. M., Baeshen, R. S., & Said-Al Ahl, H. A. (2017). Botanical insecticide as simple extractives for pest control. *Cogent Biology*, *3*(1), 1404274. https://doi.org/10.1080/23312025.2017.1404274

Kaihena, M., & Ukratalo, A. M. (2021). Daun Kayu Putih (*Melaleuca leucadendra* L) Sebagai Pengendali Larva *Aedes aegypti* Dalam Upaya Pencegahan Demam Berdarah Dengue (DBD) Di Kota Ambon. *Biofaal Journal*, *2*(1), 28-34. https://doi.org/10.30598/biofaal.v2i1pp28-34

Laila, N. (2025). Efektivitas Lilin Aromaterapi Ekstrak Daun Cengkeh (*Syzygium aromaticum*) Sebagai Insektisida Lalat Rumah (*Musca domestica*). *Jurnal Riset dan Aplikasi Kesehatan*, *1*(1).

Manandhar, A., Milindi, P., & Shah, A. (2018). An overview of the post-harvest grain storage practices of smallholder farmers in developing countries. *Agriculture*, *8*(4), 57. https://doi.org/10.3390/agriculture8040057

Martias, I., & Ajadit, N. (2020). Pengaruh ekstrak daun cengkeh (*Syzygium aromaticum* L.) sebagai repellent terhadap jumlah lalat yang hinggap selama proses penjemuran ikan asin di Senggarang tahun 2019. *Jurnal Kesehatan Terpadu (Integrated Health Journal)*, *11*(1), 8-13. https://doi.org/10.32695/jkt.v11i1.53

Molenaar, R. (2020). Panen dan pascapanen padi, jadung dan kedelai. *Eugenia*, *26*(1).

Moniharapon, D. D., Ukratalo, A. M., Hendrajid, Z., & Ramadhany, M. R. (2020). Biolarvicide of Herba Ethanol Extract of *Phyllanthus niruri* L on *Aedes aegypti* Mosquito Larva Vector Of Dengue Hemorrhagic Fever Disease (DHF). In *Journal of Physics: Conference Series* (Vol. 1463, No. 1, p. 012026). IOP Publishing. https://doi.org/10.1088/1742-6596/1463/1/012026

Moniharapon, D. D., & Ukratalo, A. M. (2021). Test the activity of larvae ethanol extract brown algae *Turbine* Sp against mortality of *Aedes Aegypti* mosquito larvae. In *AIP Conference Proceedings* (Vol. 2360, No. 1, p. 040008). AIP Publishing LLC. https://doi.org/10.1063/5.0061789

Nonci, N., & Muis, A. (2015). Biologi, gejala serangan, dan pengendalian hama bubuk jagung Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae). *Jurnal Penelitian dan Pengembangan Pertanian*, *34*(2), 30951. https://doi.org/10.21082/jp3.v34n2.2015.p61-70

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

Nuraini, I. V., Prakoso, B., & Suroto, A. (2022). Survei dan identifikasi hama gudang pada komoditas padi, jagung, dan kedelai di Kecamatan Batuwarno, Wonogiri. *Biofarm: Jurnal Ilmiah Pertanian*, *18*(2), 87-95. https://doi.org/10.31941/biofarm.v18i2.1711

Pio, R. J. (2025). *Cengkih dan Komunitas: Perjalanan Manis Pahit dari Tanah Hingga Meja*. Deepublish.

Reubun, Y. T. A., Kumala, S., Setyahadi, S., & Simanjuntak, P. (2020). Penghambatan Enzim Asetilkolinesterase dari Ekstrak Herba Pegagan (*Centella asiatica* (L.) Urb), Ekstrak Daun Kelor (*Moringa oleifera* Lam.) dan Kombinasinya. *PHARMACY: Jurnal Farmasi Indonesia (Pharmaceutical Journal of Indonesia)*, *17*(2), 451-458. https://doi.org/10.30595/pharmacy.v17i2.9052

Rustam, R., & Audina, M. (2018). Uji Tepung Biji Mengkudu (*Morinda citrifolia* L.) Terhadap Hama Bubuk Jagung *Sitophilus zeamais* M.(Coleoptera; Curculionidae). *Jurnal Agroekoteknologi*, *10*(1). https://doi.org/10.33512/j.agrtek.v10i1.5468

Rustam, R., & CinthiaTarigan, A. (2021). Uji konsentrasi ekstrak serai wangi terhadap mortalitas ulat grayak jagung. *Dinamika Pertanian*, *37*(3), 199-208. https://doi.org/10.25299/dp.2021.vol37(3).8928

Saenong, M. S. (2016). Tumbuhan Indonesia potensial sebagai insektisida nabati untuk mengendalikan hama kumbang bubuk jagung (Sitophilus spp.). *Jurnal Penelitian dan Pengembangan Pertanian*, *35*(3), 131-142. https://doi.org/10.21082/jp3.v35n3.2016.p131-142

Saputro, W. A., Viana, C. D. N., & Al Rosyid, A. H. (2023). Kontribusi dan Trend Produksi Jagung di Kabupaten Banyumas. *Agri Wiralodra*, *15*(2), 49-57. https://doi.org/10.31943/agriwiralodra.v15i2.64

Sari, N. M., Elsania, F., & Muyassaroh, M. (2020). Eugenol Dari Daun Cengkeh Menggunakan Metode Steam-Hydro Distillation Microwave Dengan Variasi Perlakuan Bahan Dan Daya Operasi. *Jurnal Teknik Kimia*, *14*(2), 51-57. https://doi.org/10.33005/jurnal_tekkim.v14i2.2026

Sasongko, P., Washington, W., & Ahmadi, K. G. S. (2022). Potensi usaha pengolahan minyak atsiri daun cengkeh di Kecamatan sipora selatan kabupaten kepulauan mentawai. *Journal of Food Technology and Agroindustry*, *4*(2), 100-115. https://doi.org/10.24929/jfta.v4i2.2127

Sembel, D. T. (2015). *Toksikologi lingkungan*. Penerbit Andi.

Senthil-Nathan, S. (2020). A review of resistance mechanisms of synthetic insecticides and botanicals, phytochemicals, and essential oils as alternative larvicidal agents against mosquitoes. *Frontiers in physiology*, *10*, 1591. https://doi.org/10.3389/fphys.2019.01591

Stejskal, V., Vendl, T., Aulicky, R., & Athanassiou, C. (2021). Synthetic and natural insecticides: Gas, liquid, gel and solid formulations for stored-product and food-industry pest control. *Insects*, *12*(7), 590. https://doi.org/10.3390/insects12070590

Tahir, M. M. (2023). *Penanganan Pasca Panen Dan Produk Olahan Sayuran*. Nas Media Pustaka.

Tahir, M., Chuzaemi, S., & Widodo, E. (2019). The performance of broilers given eugenol of clove leaf essential oil as a feed additive. *Russian Journal of Agricultural and Socio-Economic Sciences*, *95*(11), 200-205. https://doi.org/10.18551/rjoas.2019-11.28

Tahir, M., Chuzaemi, S., Widodo, E., & Hafsah, H. (2020). Chemical compounds and antioxidant contents of cloves leaves essential oil. *AGROLAND The Agricultural Sciences Journal (e-Journal)*, *7*(1), 37-44. https://doi.org/10.22487/agroland.v7i1.459

Thakur, K., Sharma, A., & Sharma, K. (2021). Management of agricultural insect pests with physical control methods. *The Pharma Innovation Journal*, *10*(6), 306-314.

Ukoroije, R. B., & Otayor, R. A. (2020). Review on the bio-insecticidal properties of some plant secondary metabolites: types, formulations, modes of action, advantages and limitations. *Asian Journal of Research in Zoology*, *3*(4), 27-60. https://doi.org/10.9734/ajriz/2020/v3i430099

Viqri, R., Femi, R., Nurul, A., & Ayu, A. (2024). Daun Cengkeh (*Sizygium aromatikum* L.) Sebagai Reppelent Alami Ikan Asin Di Kepulauan Simuelue. *Berkala Perikanan Terubuk*, *52*(3).

Wagiman, F. X. (2019). *Hama pascapanen dan pengelolaannya*. Ugm Press.

Wahab, N. H. A. (2021). Cholinesterase inhibition activity and molecular docking study of eugenol derivatives. *Sains Malaysiana*.

Wulandari, F., & Batoro, J. (2016). Etnobotani Jagung (*Zea mays* L.) Pada Mayarakat Lokal di Desa Pandansari Kecamatan Poncokusumo Kabupaten Malang. *Biotropika: Journal of Tropical Biology*, *4*(1), 17-24.

Yigit, N., & Velioglu, Y. S. (2020). Effects of processing and storage on pesticide residues in foods. *Critical reviews in food science and nutrition*, *60*(21), 3622-3641. https://doi.org/10.1080/10408398.2019.1702501