BioThink, Vol -2, Issue -2
ISSN: 3048-7943

Ginger-Derived Compounds in Insect Control: A Natural Alternative to Synthetic Chemicals

Rahul Borah [1*] and Kasturi Sarmah [2]

[1]Department of Entomology, Assam Agricultural University, Jorhat, Assam, India, [2]Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Corresponding authors E-mail: borahrahul293@gmail.com

Introduction

Plants have developed a range of physical defenses, including thickened cell walls, trichomes, spines, and protective cuticles, alongside biochemical mechanisms such as terpenes, phenolics, and defense proteins. Certain compounds like lectins, defensins, thionins, and nitrogen- or sulfur-based substances play a crucial role in deterring herbivores, contributing to their natural resistance against insect attacks—an adaptation refined over millions of years. These evolutionary traits hold great potential for sustainable pest management. Furthermore, essential oils have emerged as a promising eco-friendly alternative to chemical pesticides for future pest control strategies. (Kasturi et al. 2024).

Ginger (Zingiber officinale Rosc), a perennial herb from the Zingiberaceae family, is widely cultivated in tropical regions, where India is the largest producer country, contributing 30-40% of global production (Senapoti & Gosh 2005). Major ginger-growing states in India include Karnataka, Kerala, Meghalaya, Mizoram, Arunachal Pradesh, Nagaland, Sikkim, West Bengal, and Odisha. The rhizomes of ginger's are thick, aromatic, and yellow-brown, are commonly used as a spice and valued for their medicinal properties. Ginger has anti-nausea, analgesic, and anti-inflammatory effects and is beneficial for gastrointestinal health, blood purification, and respiratory issues (Mahboubi 2019). Its bioactive compounds contribute to its antioxidant properties and insecticidal potential. Furthermore, pungent aroma of ginger is due to its volatile oils (1-3%) such as including sesquiterpenes, zingerone, kaempferol, and zingiberene, which make it a valuable ingredient in both traditional medicine and culinary applications (Ogbonna Confidence et al.2014). In this study efforts were made to evaluate the insecticidal properties and chemical compositions of ginger.

Chemical composition of ginger extracts

Ginger rhizomes are mainly composed of carbohydrates (50%-70%) and lipids (3%-8%). The fresh rhizome's primary phenolic compounds are gingerols, which contribute to its pungency (Sinha & Ray 2024). Shogaols, formed from gingerols during drying, are more abundant in dried ginger. Further the characteristic aroma of ginger is due to volatile oils like zingiberene and bisabolene (Prashad & Tyagi 2015). Table 1 shows phenolic and terpenes compound found in different form of ginger.

Type of ginger	Phenolic	Terpenes	Ref.
Fresh ginger	Gingerol (6, 8, 10-gingerol), paradols, shogaol, 6-dehydrogingerdione quercetin, zingerone, and gingerenone-A,	β-bisabolene, α-farnesene, zingiberene, α-curcumene, and β-sesquiphellandrene	Mao et al. 2019
Dried ginger	Shogaol (6,8,10-shogaol) and gingerol		Sang et al.2020
Ginger powder	gingerol,paradols, and shogaol	ingiberene, β-sesquiphellandrene, β-bisabolene,α -curcumene,and αfarnesene,	Sinha & Ray 2024

Table-1: Phenolic and terpenes compound found in different form of ginger

Pesticidal effects of ginger

Ginger (Zingiber officinale) exhibits notable pesticidal properties, making it a valuable natural alternative to synthetic chemicals. Ginger extracts contain bioactive compounds like gingerols, shogaols, and zingiberene, which exhibit insecticidal properties affecting various physiological systems in insects. These compounds can impair the central nervous system, leading to loss of smell and food recognition, and damage the gastrointestinal tract, resulting in reduced feeding and eventual death. They also disrupt membrane metabolism, interfere with juvenile hormone and chitin synthesis, hindering growth and development. Additionally, ginger constituents can impair mitochondrial function, disrupting the electron transport chain and reducing ATP production, leading to respiratory distress and mortality in insect larvae (Sinha & Ray 2024).

Studies have demonstrated that ginger extracts, particularly from shoots, contain compounds such as quercetin-3-O-rutinoside and 6-gingerol, which exhibit aphicidal and growth-regulating effects against pests like sorghum aphids (*Melanaphis sorghi*) (Liu et al. 2022) . These compounds inhibit digestive enzymes like pepsin, α-amylase, and lipase in aphids, while stimulating superoxide dismutase (SOD) activity and repressing acetylcholinesterase (AChE), leading to increased mortality and reduced reproduction and longevity. Essential oils derived from ginger have also shown insect repellent properties. For instance, a study using a Y-tube olfactometer bioassay against Culex theileri mosquitoes demonstrated 45% insecticidal and 61% repellent efficiency of ginger essential oil (Madreseh et al. 2018). Additionally, ginger extract has been effective against the adult beetle *Oryzaephilus surinamensis*, a common pest in stored products, with an LC50 value of 0.14 mg/g through contact toxicity. The extract induced changes in insect protein configurations, increasing protein subfractions, which may contribute to its pesticidal action (Amer-Zareen et al 2003). Beyond insecticidal effects, ginger extracts exhibit nematocidal properties by altering nematodes' host recognition abilities, leading to behavioral changes. The essential oil components of ginger, such as α-zingiberene, ar-curcumene, β-sesquiphellandrene, geranial, α-farnesene, and β-bisabolene, possess antimicrobial properties, effectively inhibiting bacteria like Staphylococcus aureus, Pseudomonas aeruginosa, and Listeria monocytogenes (Mahboubi. 2019). Ginger's active constituents also function as antifeedants by targeting insects' central nervous systems, impairing sensory organs responsible for detecting food, leading to gastrointestinal tract damage, and inhibiting olfactory functions. Consequently, larvae cease feeding and succumb to weakness. Furthermore, ginger exhibits larvicidal effects by disrupting the larval respiratory system and impairing mitochondrial function, which affects the electron transport system and reduces ATP production, ultimately leading to larval death. These components also act as insect growth regulators (IGRs) and antifeedants by disrupting membrane metabolism within the gut epithelium of target insects and generating oxygen radicals through oxidation. Moreover, gingerols and dehydroshogaol affect P450-dependent ecdysone 20-monooxygenase activity, leading to the disruption of juvenile hormone (JH) levels, ecdysteroid levels, chitin synthesis, endocrine function, and antioxidant enzyme systems (Agarwal et al. 2001, Yahya et al. 2018).

Sl. no	**Major components**	**Target pest**	**Reference**
1	6-Gingerol, quercetin-3-Orutinoside	sorghum aphid (*Melanaphis sorghi*)	Liu et al. 2022
3	Crude extract	*Sitophilus oryzae* L.	Rizvi et al. 2016
5	fractions of ginger	okra flea beetles and cowpea bruchid	Felix & Echezona 2012
6	zingiberene, gingerol, dehydroshogaol	*Spilosoma obliqua*, *Rhizoctonia solani*.	Agarwal et al. 2001
7	isopropyl myristate, tetratetracontane, 17-pentatriacontene, celidoniol deoxy, a-zingiberene, Eucalyptol	*Spodoptera littoralis*	Hamada et al. 2018
8	terpenoid	*Aedes aegypti*	Yahya & anwar 2018

Table-2: Components of ginger show pesticidal effect in different species of insect

Conclusion and Future Prospects

Ginger is a promising natural alternative to synthetic pesticides due to its diverse bioactive compounds, including gingerols, shogaols, and terpenes. These constituents exhibit strong insecticidal, nematocidal, and antimicrobial properties by disrupting critical physiological functions in pests, leading to mortality. Additionally, ginger extracts function as antifeedants and insect growth regulators, making them effective against a wide range of agricultural pests. Future research should focus on optimizing extraction methods to enhance the pesticidal efficacy of ginger-derived compounds. Large-scale field trials are necessary to assess their practical application and economic viability. Additionally, exploring synergistic effects with other botanical pesticides may enhance efficacy while reducing environmental risks. Developing eco-friendly formulations, such as nanoemulsions or biopolymer-based delivery systems, can improve stability and controlled release. Overall, integrating ginger-based pesticides into sustainable pest management strategies can contribute to reducing chemical pesticide dependency and promoting safer agricultural practices.

Reference

Agarwal, M., Walia, S., Dhingra, S., & Khambay, B. P. (2001). Insect growth inhibition, antifeedant, and antifungal activity of compounds isolated/derived from Zingiber officinale Roscoe (ginger) rhizomes. Pest Management Science, 57, 289-300.

Amer-Zareen, Zaki, J. M., & Javed, N. (2003). Nematicidal activity of ginger and its effect on the efficacy of Pasteuria penetrans for the control of root-knot nematodes on tomato. Asian Journal of Plant Sciences, 2(11), 858-860.

Felix, A. C., & Echezona, B. (2012). Extraction fractions of ginger (Zingiber officinale Roscoe) and residue in the control of field and storage pests. Journal of Agricultural Technology, 8(6), 2023-2031.

Hamada, H. M., Awad, M., El-Hefny, M., & Moustafa, M. A. M. (2018). Insecticidal activity of garlic (Allium sativum) and ginger (Zingiber officinale) oils on the cotton leafworm, Spodoptera littoralis (Boisd.) (Lepidoptera: Noctuidae). African Entomology, 26(1), 84-94.

Liu, X., Xi, K., & Wang, Y. (2022). Evaluation of the contact toxicity and physiological mechanisms of ginger (Zingiber officinale) shoot extract and selected major constituent compounds against Melanaphis sorghi Theobald. Horticulturae, 8(944), 1-13.

Madreseh-Ghahfarokhi, S., Pirali, Y., Dehghani-Samani, A., & Dehghani-Samani, A. (2018). The insecticidal and repellent activity of ginger (Zingiber officinale) and eucalyptus (Eucalyptus globulus) essential oils against Culex theileri Theobald, 1903 (Diptera: Culicidae). Annals of Parasitology, 64(4), 351-360.

Mahboubi, M. (2019). Zingiber officinale Rosc. essential oil, a review on its composition and bioactivity. Clinical Phytoscience, 5(1).

Mao, Q. Q., Xu, X. Y., Cao, S. Y., Gan, R. Y., Corke, H., & Beta, T. (2019). Bioactive compounds and bioactivities of ginger (Zingiber officinale Roscoe). Foods, 8(185), 1-21.

Ogbonna, C. U., Eziah, V. Y., & Owusu, E. O. (2014). Bioefficacy of Zingiber officinale against Prostephanus truncatus Horn (Coleoptera: Bostrichidae) infesting maize. Journal of Biopesticides, 7(2), 177-185.

Okonkwo, C. O., & Ohaeri, O. C. (2013). Insecticidal potentials of some selected plants. Journal of Chemical and Pharmaceutical Research, 5(4), 370-376.

Prasad, S., & Tyagi, A. K. (2015). Ginger and its constituents: Role in prevention and treatment of gastrointestinal cancer. Gastroenterology Research and Practice, 2015.

Rani, A. (2017). Bioefficacy of extract of turmeric and ginger as potential biopesticides on Sitophilus oryzae. Advanced Scientific Research, 2(1), 10-11.

Rizvi, S. A. H., Hussain, S., Rehman, S., Jaffar, S., & Rehman, M. F. U. (2016). Efficacy of eco-friendly botanical extracts of ginger (Zingiber officinale), garlic (Allium sativum), and tobacco (Nicotiana tabacum L.) for the control of cabbage looper (Trichoplusia binotalis) under agro-ecological conditions of Peshawar, Pakistan. Journal of Entomology and Zoology Studies, 4(1), 88-90.

Sang, S., Snook, H. D., Tareq, F. S., & Fasina, Y. (2020). Precision research on ginger: The type of ginger matters. Journal of Agricultural and Food Chemistry, 68(32), 8517-8523.

Sarmah, K., Anbalagan, T., Marimuthu, M., Mariappan, P., Angappan, S., & Vaithiyanathan, S. (2024). Innovative formulation strategies for botanical- and essential oil-based insecticides. *Journal of Pest Science.* https://doi.org/10.1007/s10340-024-01846-2

Senapati, A. K., & Ghose, S. (2005). Screening of ginger varieties against rhizome rot disease complex in eastern ghat high land zone of Orissa. Indian Phytopathology, 58(4), 437-439.

Sinha, N., & Ray, S. (2024). The potential of ginger (*Zingiber officinale* Rosc.) extracts as a bio-pesticide. *Journal of Entomology and Zoology Studies*, *12*(3), 38-45.

Yahya, S. K., & Anwar, C. (2018). The efficacy of red ginger fraction (Zingiber officinale Roscoe var. rubrum) as insecticidal Aedes aegypti. Bioscientia Medicina, 2(2), 31-41.