



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

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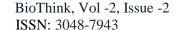
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Introduction

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 yellowbrown, are commonly used as a spice and valued for their medicinal properties. Ginger anti-nausea. analgesic, has and antiinflammatory effects and is beneficial for gastrointestinal health, blood purification, and respiratory issues (Mahboubi 2019). Its bioactive compounds contribute to antioxidant properties and insecticidal potential. Furthermore, pungent aroma of ginger is due to its volatile oils (1-3%) such 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.

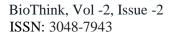
Type of ginger	Phenolic	Terpenes	Ref.
Fresh ginger	Gingerol (6, 8, 10-gingerol),	β-bisabolene, α-farnesene,	Mao et
	paradols, shogaol, 6- dehydrogingerdione	zingiberene, α -curcumene, and β -	al. 2019
	quercetin, zingerone, and	sesquiphellandrene	
	gingerenone-A,		
Dried ginger	Shogaol (6,8,10-shogaol)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

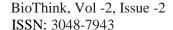




impair the central nervous system, leading to loss of smell and food recognition, and damage the gastrointestinal tract, resulting in reduced feeding and eventual death. They also disrupt membrane metabolism, interfere with juvenile hormone and chitin synthesis, hindering growth and development. Additionally, ginger constituents can impair function. mitochondrial disrupting 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-Orutinoside 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 increasing configurations, 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 zingiberene, ar-curcumene, βsesquiphellandrene, 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 weakness. Furthermore, ginger exhibits larvicidal effects by disrupting the larval respiratory impairing system and 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 radicals through oxygen Moreover, gingerols oxidation. and dehydroshogaol P450-dependent affect 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	Liu et al. 2022
		sorghi)	
3	Crude extract	Sitophilus oryzae L.	Rizvi et al.
			2016
5	fractions of ginger	okra flea beetles and cowpea	Felix &
		bruchid	Echezona
			2012
6	zingiberene, gingerol, dehydroshogaol	Spilosoma obliqua,	Agarwal et al.
		Rhizoctonia solani.	2001
7	isopropyl myristate, tetratetracontane,	Spodoptera littoralis	Hamada et al.
	17-pentatriacontene, celidoniol deoxy,		2018
	a-zingiberene, Eucalyptol		
8	terpenoid	Aedes aegypti	Yahya &
			anwar 2018

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





Conclusion and Future Prospects

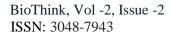
Ginger is a promising natural alternative to synthetic pesticides due to its diverse bioactive compounds, including gingerols, shogaols, and terpenes. These constituents exhibit strong insecticidal, nematocidal, and by antimicrobial properties disrupting critical physiological functions in pests, leading 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 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 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.

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