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Essential Oils- A Natural Alternative for Storage Pest Management

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Abstract

Ensuring food security is a growing challenge, especially with increasing post-harvest losses caused by storage pests and fungi. Conventional pest management methods, including synthetic insecticides and fungicides, pose risks such as pesticide resistance, environmental contamination, and health hazards. Essential oils derived from plants and their components offer a promising alternative for storage pest and fungi management due to their insecticidal and antifungal properties. However, their efficacy is often limited by volatility, oxidation, and water solubility. To combat these challenges, advanced formulations such as nanocomposites and bio-composites can enhance stability, prolong their shelf life through slow and controlled release while maintaining mammalian safety.

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1. Introduction

The world population may increase nearly up to 9.8 billion in 2050 than the existing population of 7.6 billion. There also might be a food scarcity if the world food production is not increased by 70% by the year 2050 (Singh et al., 2021). Food grains and pulses are the main source of food in such insecurity phases. Certainly, about 70 % of the produced grains are stored in villages in the traditional structures such as earthen pots, silos, gunny bags etc., About 10% of post harvest losses are due to the stored pests viz., insects, rodents and pathogens. Some microorganisms like *Aspergillus, Penicillium,* and *Fusarium* expels or produce mycotoxins on food material which is capable of causing disease and death in both humans and other animals and thus make the food unsafe for consumption.

Among these, insect pests alone cause a loss of Rs. 1300 crores (Banga et al., 2018). Fumigation with phosphine to a large consignment of various stored grain products is an economically feasible and safest option for the management of insect pests. Due to the international agreements, the usage of fumigant methyl bromide, the dependence on phosphine is increasing noticeably in stored grain pest management in the recent past (Rajendran, 2001). Hence, phosphine is the only fumigant of choice for pest control in storage. The indiscriminate, sub lethal dosages and

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continuous use of phosphine in poorly sealed warehouses resulted in the development of phosphine resistance in many of the stored grain pests especially in bulk storage facilities and that was worsened further by the lack of suitable alternatives. Usage of fungicides is also causing the same challenge (fungal resistance) against storage fungi. Besides, repeated applications can be expensive, especially for small-scale farmers. Therefore, increasing concern over safe food and environment, there is a need for safe and eco-friendly technology for management of storage pests. Essential oils (EOs) extracted from plants (*Syzygium aromaticum*, *Eucalyptus* spp., *Ocimum* spp., *Citrus* spp., *Mentha* spp., *Acorus calamus etc.*,) are one of the tools for stored insect pest management.

2. Essential Oil and their Components as Insecticides

Essential oils are complex molecules containing volatile secondary metabolites which are extracted by steam distillation from aromatic plants. The volatile compounds include terpenes (monoterpenes and sesquiterpenes) and phenolic compounds. The EOs constituted by 20 to 70 organic molecular components. The components having insecticidal properties against various insect pests are listed in Table 1. The bioactivity of EOs are contact toxicity, repellent, fumigant toxicity, antifeedant activity, inhibition of acetylcholinesterase, disruption of insect hormone system etc.

3. Essential Oil and their Components as Fungicides

Essential oils and their components have various mode of actions against storage fungi (Table 2 and Figure 1). The antifungal properties are due to accumulation of EOs in bi-lipid cell layer lipophilic hydrocarbons. EOs not only inhibit the mycelial growth and spore formation but also forms biofilms. Biofilms are sessile microbial structures attached to surfaces or each other and protected by polymeric extracellular matrix (ECM). Biofilm cell communities have more resistance than planktonic cells to antifungal drugs. In such cases, EOs plays a vital role on resistant strains of stored fungus. Peppermint, eucalyptus, ginger grass and clove EOs acts as potent antifungal agents and also forms biofilm against *C. albicans*. Eucalyptus oil provides best results as antifungal agent compared to the conventional drug fluconazole. EOs also act on alteration and inhibition of cell wall formation. The essential oil extracted from *Citrus sinensis* epicarp (contains limonene-84.2%) is able to inhibit the growth of *Aspergillus niger* and also caused deleterious morphological alterations (irreversible) (Gogoi et al., 2008). While some EOs affect the mitochondrial functioning by inhibiting mitochondrial dehydrogenases which are involved in ATP synthesis. An

Table 1: Insecticidal properties of essential oil components against various storage insect pests (Nenaah et al., 2015; Fouad et al., 2023)

Essential oil	Component	Type of secondary metabolite	Storage insect pest	Insecticidal property
Sweet flag oil (*Acorus calamus*)	β-asarone	phenylpropanoid	*Callosobruchus maculatus*	Contact and fumigant toxicity
Clove oil (*Syzygium aromaticum*)	Eugenol	Monoterpene	*Rhizopertha dominica*	Inhibit acetylcholinesterase
Thyme oil (*Thymus vulgaris*)	Thymol, Carvacrol	Phenol	*Tribolium castaneum*	disrupt the nervous system of insects
Yarrow oil (*Achillea millefolium*)	β-caryophyllene	Sesquiterpene	*Callasobruchus maculatus*	Repellent
Spearmint oil, peppermint oil (*Mentha* sps.)	Carvone	Ketones	*Callasobruchus chinensis*	Interfering with the hormonal systems of insects
Lavender (*Lavandula angustifolia*) and basil (*Ocimum basilicum*)	Linalool	Monoterpene	*Sitophilus zeamais*	Repellent
Oregano (*Origanum vulgare*)	Carvacrol	Monoterpene	*Sitophilus zeamais*	Disrupt the nervous system of insects
Rosemary (*Rosmarinus officinalis*)	α-Pinene	Monoterpene	*Sitophilus zeamais*	Contact toxicity and repellent
Citronella oil (*Cymbopogon nardus*)	Citronellal	Monoterpene	*Sitophilus zeamais*	Repellent

Table 2: Essential oils and their bioactive compounds: Mode of action against storage fungi (Nazzaro et al., 2017)

Essential oil	Component	Storage fungi	Mode of action on storage fungi
Mountain pepper (*Litsea cubeba*)	citral	*Fusarium moniliforme, F. solani, Alternaria alternata* and *A. niger,*	Damage their cell wall and cell membrane
Masuri Berry (*Coriaria nepalensis*)	α-pinene, limonene	*C. albicans*	Inhibit the ergosterol biosynthesis
Clove oil (*Syzygium aromaticum*)	Eugenol	*Drug resistant strains of C. albicans.*	Antifungal activity
Thyme oil (*Thymus vulgaris*)	Thymol, Carvacrol	*Alternaria, Aureobasidium* and *Penicillium*	Biofilm formation
Eucalyptus and peppermint oil (*Mentha piperita*)	1, 8-cineole and menthol,	*C. albicans*	Antifungal activity
Dill (*Anethum graveolens*)	Carvone	*C. albicans*	Inhibition of ATP synthesis in the mitochondria

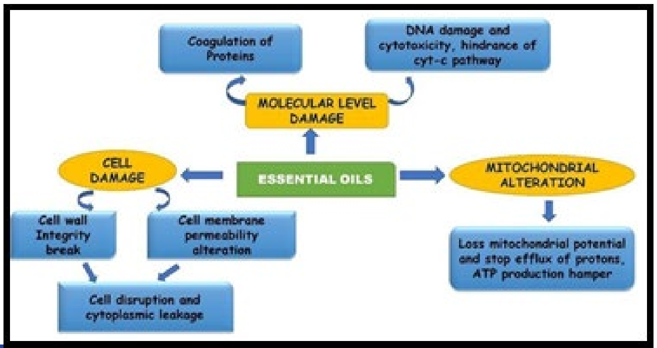

Figure 1: Mode of action of essential oils on fungal pathogens (Anirbani et al., 2020)

extract of dried fruits of *Xylopia aethiopica* (Annonaceae) and dry seeds of the pepper *Piper guineense* was even able to completely prevent development of *Aspergillus flavus.*

4. Conclusion

Though essential oils activities are promising against storage insect pest and fungi, but there are also challenges on the application of essential oils like essential oils volatility, oxidation and water solubility which play an important role in persistence of the essential oil compounds. The problem can be rectified by developing new formulations like nanocomposites or bio-composites. They protect the essential oils from degradation, and increase their shelf life by reducing evaporation. Additionally, they increase the persistence by slow, controlled release and increases the surface area, solubility and mobility while maintaining low mammalian toxicity

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