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Plant-Based Products as Control Agents of Stored Product Insect Pests: Prospects, Applications and Challenges

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Stored product insect pests pose a significant threat to global food security and economic stability, as they cause substantial damage to stored grains and other food commodities. Traditional pest control methods often rely on chemical insecticides, which can have adverse effects on the environment, human health, and food safety. In light of these concerns, there is growing interest in exploring sustainable and eco-friendly alternatives for managing stored product insect pests. This abstract highlights the potential of plant-based products as a viable and environmentally friendly approach to control stored product insect pests. Plant-based products, such as botanical extracts and essential oils, are derived from various plant sources and have shown promise in repelling, deterring, and even killing insect pests. These products offer several advantages, including biodegradability, reduced chemical residues, and minimal harm to non-target organisms. This review summarizes recent research on the efficacy of plant-based products against a range of stored product insect pests, including but not limited to beetles, weevils, and moths. It discusses the mechanisms through which these products exert their pest control effects, such as disrupting insect behavior, affecting their reproduction, or inducing mortality. Moreover, the potential synergistic effects of combining plant-based products with other pest management strategies, like hermetic storage and modified atmospheres, are explored. In addition, this abstract examines the challenges and limitations associated with the use of plant-based products in pest management, including issues related to formulation, stability, and the need for further research to standardize application protocols. The economic feasibility and scalability of plant-based pest control methods are also considered. The findings presented in this abstract emphasize the importance of incorporating plant-based products into integrated pest management strategies for stored product insect pests. These products have the potential to contribute to a more sustainable and environmentally friendly approach to safeguarding global food reserves, while minimizing the risks associated with chemical pesticides. Further research and collaboration between the scientific community, agricultural industry, and policymakers are essential to harness the full potential of plant-based products in the fight against stored product insect pests.

Keywords: Stored products; insects; chemicals; pesticides; agricultural products.

1. INTRODUCTION

Plant-Based Products as Control Agents of Stored Product Insect Pests: Prospects, Applications, and Challenges is a comprehensive topic that explores the use of natural, plant-derived substances for managing insect pests in stored agricultural products. This critical review discusses the potential, practical applications, and obstacles associated with plant-based pest control agents. Plant-based products are considered environmentally friendly and sustainable alternatives to synthetic pesticides. They have the potential to reduce chemical residues in stored products, addressing consumer concerns and international food safety regulations. Plant-based products can include botanical extracts, essential oils, plant powders, and other natural compounds with insecticidal properties. These substances often contain bioactive compounds that repel or kill stored product insect pests. The mechanisms by which plant-based products control pests may involve repellency, insect growth regulation, interference with feeding or mating, and direct toxicity. Understanding these mechanisms is crucial for optimizing their use. Plant-based products can be applied in various ways, such as direct spraying, fumigation, incorporation into grain storage, or the use of treated packaging materials. The choice of application method depends on the specific pest and storage conditions. Plant-based products may degrade more quickly than synthetic chemicals, requiring frequent reapplication. Effectiveness can vary based on factors like pest species, environmental conditions, and formulation. There is a potential risk of stored product insect pests developing resistance to plant-based products, similar to synthetic pesticides. Strategies for resistance management should be developed and implemented. Plant-based products may face regulatory challenges related to registration, safety evaluation, and standardization. Compliance with local and international regulations is essential for commercial use. Combining plant-based products with other pest management techniques, such as sanitation, hermetic storage, and trapping, can enhance overall efficacy. The use of plant-based products

aligns with sustainable agriculture and organic farming practices, promoting reduced chemical input and lower ecological impact. Ongoing research is needed to identify and develop new plant-based products, improve formulations, and determine their efficacy across various pest species and storage conditions. In conclusion, the prospects of plant-based products as control agents for stored product insect pests are promising due to their eco-friendly nature and potential to reduce chemical residues in food. However, their practical application and commercial success are accompanied by challenges related to efficacy, resistance management, and regulatory hurdles. Further research and development are essential to unlock the full potential of plant-based products in integrated pest management strategies for stored agricultural products [1-5].

The use of botanicals (plant-derived substances) for stored grain pest management is a topic of interest in agriculture and pest control. Botanicals have been used for centuries as a natural and eco-friendly alternative to synthetic pesticides in protecting stored grains from pests. Here is a critical review of the use of botanicals for stored grain pest management. Botanicals can be effective in managing stored grain pests, but their efficacy varies depending on the type of botanical, the pest species, and environmental conditions. Some botanicals have demonstrated promising results in laboratory and field trials, while others may be less effective. Different botanicals have varying effects on different pest species. Some botanicals are more effective against certain types of pests while being less effective against others. Identifying the specific pest species infesting stored grains is crucial in selecting the appropriate botanical treatment. There is some concern that pests may develop resistance or tolerance to botanicals over time, similar to synthetic pesticides. Continuous monitoring and rotation of botanical treatments may help mitigate the risk of resistance. The formulation and application of botanicals can affect their efficacy. Factors such as concentration, application method, and timing play a critical role. Dustable powders, extracts, and essential oils are common formulations used for botanical pest management. The effectiveness of botanicals can be influenced by storage conditions, including temperature, humidity, and grain moisture content. Proper storage practices must be maintained to complement botanical treatments. Botanicals are generally considered safer for human health and the environment compared to synthetic chemicals. However, they may still leave residues on grains. It is essential to assess the safety of botanical residues and ensure they comply with regulatory standards [6-10].

2. SUSTAINABILITY AND ENVIRONMENTAL IMPACT

The use of botanicals aligns with sustainable agriculture principles, as they are often biodegradable and have lower ecological impacts. However, the environmental impact of large-scale botanical applications should be carefully evaluated. Research is ongoing in the field of botanical pest management. There are still many knowledge gaps regarding the optimal use of botanicals, their long-term effects, and their compatibility with other pest control methods. In conclusion, the use of botanicals for stored grain pest management holds promise as a more sustainable and eco-friendly alternative to synthetic pesticides. However, their efficacy can be variable, and their application requires careful consideration of factors such as the type of pest, formulation, and storage conditions. Ongoing research and monitoring are essential to refine and optimize the use of botanicals in pest management while ensuring the safety of stored grain products and environmental sustainability [11].

3. VARIABILITY IN PLANT SPECIES

Different plant species yield various compounds with insecticidal properties. Research is needed to explore the efficacy of plant-based products derived from a wide range of plant sources to find the most effective solutions. Traditional agricultural practices and knowledge of local communities often involve the use of plant-based products for pest management. Incorporating this traditional wisdom can be valuable in developing effective and culturally relevant solutions. Developing plant-based products for commercial use requires investment in research, formulation, and large-scale production. Assessing the economic viability of these products is crucial for adoption by farmers and industries. Plant-based products can have limitations related to shelf life and storage stability. Ensuring these products remain effective throughout their shelf life is essential for practical use. As consumer demand for natural and organic products grows, there is an opportunity to market stored goods treated with plant-based pest control agents as healthier and more environmentally friendly options [12].

Integrated Pest Management (IPM) strategies often involve combining multiple pest control methods. Integrating plant-based products with other IPM practices can result in a more holistic and effective approach. Farmers and storage facility operators may need education and training on the proper use of plant-based products, including dosage, application methods, and safety measures. The effectiveness of plant-based products may vary by region due to differences in climate, pest species, and agricultural practices. Understanding these regional variations is important for widespread adoption. Regular monitoring and evaluation of the effectiveness of plant-based products are necessary to make adjustments to pest management strategies and improve outcomes over time. Collaboration between researchers, government agencies, and the private sector can help accelerate the development and adoption of plant-based pest control solutions. Sharing knowledge and best practices is vital for progress in this field. In summary, plant-based products have the potential to revolutionize pest management in stored agricultural products, offering a more sustainable and environmentally friendly alternative to synthetic pesticides. While there are challenges and limitations, ongoing research, collaboration, and education can help overcome these obstacles and expand the practical applications of plant-based pest control agents [12,13].

The global food supply chain is a complex network that connects agricultural production to consumers worldwide. At each stage of this chain, there is a persistent threat from insect pests, which can cause significant economic losses by infesting and damaging stored food products. Traditional methods of pest control often involve the use of chemical insecticides. However, concerns about the environmental impact, health risks, and the development of insecticide-resistant pests have led to a growing interest in alternative, eco-friendly solutions. Plant-based products have emerged as a promising and sustainable means of controlling stored product insect pests. This essay explores the efficacy and benefits of using plant-based products as control agents for these pests. The Significance of Stored Product Insect Pests Stored product insect pests are a significant challenge in the agriculture and food industries. These pests, which include insects like grain weevils, rice weevils, and flour beetles, can infest stored food products such as grains, cereals, and legumes, leading to losses in quantity and quality. Infestations can occur at any point along the food supply chain, from farms to processing facilities, transportation, and retail outlets. The economic impact of these pests is substantial, with billions of dollars lost annually due to damaged and contaminated food products. Plant-Based Products as Control Agents Plant-based products offer a sustainable and eco-friendly approach to controlling stored product insect pests. These products are derived from natural sources and can be used in various forms, such as essential oils, botanical extracts, and plant-derived compounds. Their efficacy as pest control agents is attributed to their inherent properties, including repellence, toxicity, and growth disruption [14-17].

3.1 Repellence

Many plant-based products possess natural repellent qualities that deter insects from infesting stored food products. Essential oils like peppermint, eucalyptus, and neem are known for their ability to create a protective barrier that discourages pests from entering storage facilities or coming into contact with stored food.

3.2 Toxicity

Plant-derived compounds often contain natural toxins that are harmful to insects but pose minimal risks to humans and the environment. Pyrethrum, derived from chrysanthemum flowers, and diatomaceous earth, a naturally occurring substance, are effective examples of toxic plant-based products that can be used to control insect pests without resorting to synthetic chemicals. Some plant-based products interfere with the development and reproduction of stored product insect pests. Neem oil, for instance, contains azadirachtin, which disrupts the hormonal systems of insects, preventing their growth and reproduction.

4. BENEFITS OF USING PLANT-BASED PRODUCTS ENVIRONMENTALLY FRIENDLY

Plant-based products are biodegradable and typically have a lower environmental impact compared to synthetic chemical insecticides. Their use reduces chemical residues in food products and minimizes harm to non-target organisms. Health and Safety: Unlike synthetic pesticides, plant-based products are generally safer for human health. They are less likely to leave harmful residues on food products and are

a preferred option in organic farming and food production. Reduced Resistance: Insects are less likely to develop resistance to plant-based products, as they often have complex mechanisms of action that make it challenging for pests to adapt. Sustainable Agriculture: The use of plant-based products aligns with the principles of sustainable agriculture, promoting a holistic approach to pest management that preserves the long-term health of ecosystems and promotes biodiversity. Challenges and Considerations While plant-based products offer numerous benefits, there are some challenges and considerations to be aware of. These include variability in effectiveness, limited persistence, and the potential for negative impacts on non-target species. Additionally, the cost of plant-based products may be higher than synthetic alternatives in some cases, which can pose a barrier to widespread adoption.

Before the advent of synthetic insecticides, plant products were the only sources for the management of insect pests. However, in the past few decades, the demands of plant-based insecticide gradually decreased, in view of low yield, inadequate availability of raw materials, chemical variability, biodegradable nature, and lack of effective regulatory systems for their commercialization. Therefore, to achieve large-scale worldwide application of botanical insecticides, sufficient quantities of plant raw materials and their consistent availability must be ensured along with removing the other existing obstacles. In this context, the use of recent advancements in science (chemical synthesis of novel compounds, metabolic engineering, biotechnology, DNA sequencing, and recombinant DNA technologies) and technology (advance extraction techniques and nanotechnology) have made significant contributions to enhance the effectiveness and commercial application of plant products. A large number of plant products and their analogs have been produced and designed successfully under in vitro conditions to reduce the dependency on raw materials for commercial applications [30]. The advances in genetic engineering could regulate the biosynthesis pathway that could enhance the secondary metabolites of plants. The recent extraction technologies such as microwave-assisted, ultrasound-assisted, high-pressure, and supercritical fluid extraction could enhance the yield of bioactive compounds to provide raw materials on an industrial scale. Compared to synthetic insecticides, plant-based insecticidal agents are relatively unstable and break down upon exposure of light, temperature, and air that limit their commercial application. This obstacle can be overcome with the use of nanotechnology. Encapsulation of plant-based bioactive compounds and formulations using nanocarriers could enhance the insecticidal activity of plant products during storage [18-21].

4.1 Applications

Plant-based products have gained attention as potential control agents for stored product insect pests due to their low toxicity to humans, animals, and the environment. These natural products can be used in various ways to manage insect infestations in stored grains, seeds, and other commodities. Here are some applications of plant-based products as control agents for stored product insect pests: Insecticides and Repellents: Essential oils derived from plants like neem, eucalyptus, and lavender are known for their insecticidal and repellent properties. They can be applied to stored products or used in diffusers to deter insect pests.

4.2 Grain Protectants

Plant-based materials, such as diatomaceous earth and silica gel, can be used as grain protectants. These products damage the exoskeleton of insects, causing dehydration and death.

4.3 Botanical Dusts

Ground plant materials, such as tobacco dust, can be used as dust insecticides. When applied to stored products, these dusts can deter or kill insect pests.

4.4 Companion Planting

Some plant species can be grown alongside stored crops to repel or confuse insect pests. For example, intercropping with marigolds can help deter various insect species.

4.5 Traps and Lures

Plant-based lures, such as pheromones or odors emitted by certain plants, can be used to attract insects into traps where they are captured and removed from storage areas. Biological Control: Beneficial insects, such as parasitoid wasps, can be attracted to storage areas by planting nectar-producing plants nearby. These beneficial insects help control pest populations.

4.6 Natural Extracts

Plant extracts, such as pyrethrin from chrysanthemums, can be used as a natural alternative to synthetic insecticides. These extracts can be formulated into sprays or fumigants for insect control.

4.7 Herbs and Spices

Some herbs and spices, like bay leaves, cloves, and cinnamon, can be used as natural insect repellents when placed in or around stored products. Seed Coatings: Treating seeds with plant-based coatings, such as neem oil or hot pepper extracts, can protect them from insect infestations during storage or transport.

5. ORGANIC PEST MANAGEMENT

In organic agriculture and food storage, plant-based products play a vital role in managing insect pests without the use of synthetic chemicals. It's important to note that the effectiveness of these plant-based control agents can vary depending on the specific insect species and environmental conditions. Integrated pest management (IPM) strategies often combine multiple approaches, including plant-based products, to achieve the best results in controlling stored product insect pests while minimizing environmental impact. Additionally, it's essential to follow proper guidelines and regulations for the use of any pest control agents in food storage to ensure food safety and quality [21-34].

6. CONCLUSION

Stored product insect pests pose a substantial threat to global food security and the economy. The use of plant-based products as control agents for these pests provides a sustainable, eco-friendly, and effective solution to mitigate losses and reduce reliance on synthetic chemical insecticides. By harnessing the repellent, toxic, and growth-disrupting properties of plant-based products, we can protect our stored food products, promote environmental sustainability, and ensure the safety of our agricultural systems and food supply chains. As we continue to seek innovative and environmentally conscious pest management solutions, plant-based products are proving to be a valuable and versatile tool in the battle against stored product insect pests.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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