

# Traditional Insect Control Methods in Post-Harvest Storage: Scientific Insights for Sustainable Food Security

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## Abstract

The problem of insect infestation, especially in the post-harvest management of grains, pulses, and oilseeds, is a major issue in the food chain of our world, resulting in a loss of a large quantity and quality of food products. Even though the use of chemical pesticides is a common practice for controlling insect pests, the problem of chemical residues and environmental pollution, along with the problem of pest resistance, arose subsequently. The adoption of conventional methods of insect control, which were made by experience accumulated over a period of years, is a cheap, eco-friendly, and culturally acceptable approach for the post-harvest management of insect pests. The methods of insect control include the use of botanicals like neem, tulsi, eucalyptus, and custard apple, oils like edible and non-edible oils, ash, and inert substances, as well as the use of specific storage structures like earthenware bins, bamboo, and mud. Mechanistically, these methods act as repellents, antifeedants, growth inhibitors, and suppressors for insect pests, which leads to less loss of grain quality as a consequence of insect pest management. Scientific research has accepted the indigenous approaches for insect pest management. In spite of this, challenges like the lack of standardization, dosage, as well as a conducive policy environment, still persist as hurdles to embracing these techniques. Blending indigenous knowledge systems and current post-harvest technology has the possibility to enhance food security, health, and storage sustainability.

## 1. Introduction

Post-harvest protection of crops has been recognised as one of the important, but relatively less appreciated, aspects of sustainable agriculture. In spite of the quantum leap experienced in agricultural production, a very large proportion of the crop harvested tends to perish due to pest infections during what is called the post-harvest period of crop production. This happens in spite of enormous investment in land, water, energy, and manpower. This, in a sense, makes crop production sustainability and profit threatened by pest infections alone. Hence, the importance of pest control in post-harvesting is one of the vital aspects in sustaining the gains obtained in the farms.

Moreover, the loss that is incurred during the insect-infested storage is not just based on the amount of grains that have been lost; it is also related to the quality of the grains that have deteriorated, such as the nutrients that have been depleted, portions of insects that have contaminated them, and the chances of developing microbial and fungal

contamination. The insects associated with the storage facilities, such as *Sitophilus*, *Tribolium*, and *Clonorchis*, can easily propagate and reproduce in large numbers, and therefore, a chain reaction of losses is achieved. As far as food security is concerned, these hidden losses contribute to the reduction of safe and nutritious foods, especially for small-scale farmers and poor consumers.

Chemical insecticides have dominated the major methods of controlling insects in the post-harvesting phase of the crops during the last several decades. However, with the growing concerns about residues, insect resistance, and health risks, the methods currently in practice have undergone reevaluation. In this context, some of the traditional methods of controlling insects have been recognised and developed over the years on the basis of observations and experiences.

## 2. Post-Harvest Insect Infestation: Scale and Scientific Evidence

Post-harvest insect infestation is one of the major biological hazards to the world's stock of food commodities. A big number of insect species have been reported to infest cereals, pulses, oilseeds, and processed foods during storage in granaries, with the level of damage generally being at its maximum in the tropics and subtropics. Major storage insects have been characterized to include primary feeders such as *Sitophilus oryzae* (grain beetle) and *Sitophilus zeamais*, *Rhyzopertha dominica*, and *Callosobruchus* spp., which infest whole grains, including pulses. Secondary storage pests comprising *Tribolium castaneum* (red flour beetle) and *Oryzaephilus surinamensis* (saw-toothed grain beetle) prefer broken grains, which adds to the damage, mainly from products processed from grains.

The kind of damage caused by these storage insects can be quantitatively as well as qualitatively damaging. Quantitatively, it can be easily explained as caused by direct damage from these insects. It leads to weight loss, an increase in breakage, and a loss of germinating power. Scientific investigations have revealed that the loss of 10-30% of grains stored can be due to insect damage. It can be even greater in traditional storage methods, as they may not provide adequate protection against these insects. But even more damaging is the qualitative kind of damage. There is a loss of protein and carbohydrates, an increase in free fatty acids, an increase in grain ageing, as well as an increase in the growth of fungi, including toxigenic fungi, in grains.

Apart from the physical effect, the consequences of insect infestation in grains during the post-harvest phase are

varied, both in health and economic implications. When there is an infestation of grains in storage and contaminants such as parts of the insects, their dung, as well as various microorganisms, there may arise a decrease in grain acceptability and potentially allergens and hygiene concerns. From an economic point of view, during insect infestation of grains in storage, there is an incurred loss equivalent to the value of the stored grains. This is evident in the economy of the small-scale farmer who may store food crops for an extended period for both consumption and later sale. This directly affects an aspect of livelihood security. This process is not only technical but also essential in addressing the issue of safe, nutritious, and affordable food products.

### 3. Traditional Insect Control Methods: An Overview of Indigenous Practices

Conventional ways of insect management at the postharvest storage level are deeply embedded in geographical, climatic, and cultural settings of farming communities. Farmers in Asia, Africa, and Latin America have devised their own approaches to protect the stored food materials using resources available in their environment. These approaches are highly diverse depending on the agroecological settings, type of crops, and socio-cultural practices, which indicate a great diversity of indigenous knowledge systems.



**Fig. 1. Different Techniques of Traditional Storage Practices**

Native methods of insect control can be broadly grouped into various types. One such type is the use of botanicals such as leaves, seeds, extracts of certain plants with insect growth retardant properties, inert substances like ash, sand, soil, among others, which affect insect movement, edible as well as non-edible oils used as a coating on grains and legumes, traditional storage facilities, as well as certain physical

ways of processing, which included earthen Bins, Herbal plant based, oil treated in grains and ash layering as depicted in Fig. 1. While these methods may be based on a singular mode of effecting product protection, they may conceivably be controlled by a combination of repellence, disruption, as well as an undesirable micro-environment.

### 3. Traditional Insect Control Methods: An Overview of Indigenous Practices

The traditional methods of insect control during post-harvest storage depict a range of geographical, ecological, and cultural diversity. In different parts of the agricultural community, different storage methods have been adopted as per the geographical location. In some parts, storage methods in humid tropical environments are geared towards moisture management and insects repellents. In the arid and semi-arid environments, storage methods geared towards physical barriers and desiccants have been emphasized. These region-specific storage methods show the strong linkage that exists between indigenous storage methods and agro-ecosystems.

These traditional methods can be generally categorized into different groups, which can overlap to varying degrees. Botanical methods make use of leaves, seeds, oils, and powder from plants, which kill or repel insects. Various physical and inert materials are also employed. These materials include ash, sand, and soil, which interrupt the living and moving capabilities of the insects. Structural methods make use of earthenware containers, bamboo storage, and mud storage. In addition, structural methods also make use of sun drying and smoking to create an environment for the development of insects.

The effectiveness of these traditional methods is closely linked to the transfer of knowledge from one generation to another. The methods of storing these insects have been passed on from one generation to another through oral and practical knowledge. The knowledge gained over the years enabled them to manage the storage insects sustainably without the need to rely on external aids. However, the diminishing indigenous knowledge over the years through modernization is a testament to the need to adopt and foster the knowledge within modern methods of postharvest management.

### 4. Botanical-Based Traditional Insecticidal Practices

Botanicals have been the core inputs to manage insects within the context of storage systems. Of these, neem (*Azadirachta indica*), eucalyptus (*Eucalyptus* spp.), tulsi (*Ocimum sanctum*), and custard apple (*Annona squamosa*) have gained recognition with respect to various agro-climatic zones based on their proven efficacy of repelling or killing the inhabiting storage pests apart from this various botanical used for an Insecticidal activity which listed in Table 1. The leaves, seeds, powders, and oil extracted from these botanicals are blended with the grains or used as liners for storage containers.

The efficacy of these botanicals has been attributed to their unique mode of action. Neem limonoids, like azadirachtin, salannin, and nimbin, show exceptionally good antifeedant, repellent, and growth-regulatory activity against insects. Also, eucalyptus leaves and oils contain volatile terpenoids that exhibit fumigant and repellent activity against storage pests. In tulsi, aromatic compounds that show activity on orientation patterns of insects, as well as on feeding, may be present, while in custard apple seed powder, acetogenins that show contact toxicity and growth-regulatory activity may also be present.

There has been significant scientific research which has provided substantial evidence of the effectiveness of these plants against important pests of grains, such as *Sitophilus*, *Tribolium*, *Callosobruchus*, and others. Experiments conducted to determine the efficacy of botanicals have proved to reduce the level of infestation, growth of the pest populations, and damage to grains, thus confirming conventional findings, highlighting the importance of these methods, which have proved to be environmentally safe, biodegradable, and non-toxic.

**Table 1. Botanical Materials Used in Storage, Active Compounds, and Insect Control Effects**

Botanical material	Plant part used	Major active compounds	Primary mode of action	Target storage insects
Neem ( <i>Azadirachta indica</i> )	Leaf, seeds, oil	Azadirachtin, salannin, nimbin	Repellency, antifeedant activity and growth inhibition	<i>Sitophilus</i> , <i>Tribolium</i> , <i>Callosobruchus</i>
Eucalyptus ( <i>Eucalyptus spp.</i> )	Leaf, oil	1,8-cineole, terpenoids	Repellent and fumigant action	<i>Tribolium</i> , <i>Oryzaephilus</i>
Tulsi ( <i>Ocimum sanctum</i> )	Leaf	Eugenol, linalool	Repellency, feeding deterrence	<i>Sitophilus</i> , <i>Callosobruchus</i>
Custard apple ( <i>Annona squamosa</i> )	Seeds, leaf	Acetogenins	Contact toxicity and growth suppression	<i>Callosobruchus</i> , <i>Sitophilus</i>

**5. Use of Oils, Ash, and Inert Materials in Stored Food Protection**

The application of oils, ash, and other inert materials constitutes one of the most common traditional methods for the protection of stored food commodities against insect infestation. Edible and non-edible oils from mustard, groundnut, sesame, and castor oil are frequently used as a thin layer on grains and pulses. The oils act primarily by physical

modes of action by creating a surface layer that inhibits insect respiration, egg adhesion, and larval development. In certain cases, the bioactive principles in plant-based oils also contribute to repellency and reduction in insect feeding. Ash, sand, and soil-based materials were also widely used by adding them to grains or layering the materials in storage containers. Wood ash has been extensively used due to its particle size. On one hand, inert materials are related to surface abrasion, which exceeds water loss by insects, thus subjecting insects to desiccation. Besides, inert materials inhibit insects from moving, mating, and ovipositing.

From the perspective of mechanisms of action, the traditional materials do not rely on acute toxicity to assert their effectiveness but rather on the unfavourable ecological conditions they provide to insects. Their affordability, availability, and absence of health risks make them even more relevant in the context of post-harvest protection.

**6. Traditional Storage Structures as Passive Insect Control Systems**

Traditional storage designs include earthen bins, bamboo granaries, and mud silos, which have played a major role in preventing post-harvest food materials from infestation by insects. These are usually fabricated from locally available materials and matched for the prevailing climatic conditions. In addition to serving as containers for storage, such designs also serve as passive means of control against insects through creation of an environment that is not ideal for its development.

Among the major advantages of such designs are the controlling of ventilation, temperature, and moisture. The earth and mud materials naturally have insulation properties for temperature regulation, while their pervious nature makes them control the air movements, hence preventing the accumulation of moisture within their walls. The granaries elevated on bamboo raised their base help to minimize exposure to moisture from the ground and also limit the entry of insects, hence reducing its infestation chances. The grain moisture should also be kept below critical levels as high temperatures and humidity were proven to accelerate the reproduction of insects.

Structurally, the storage facilities have narrow openings, smooth walls, and elevated floors, which all contribute to preventing the entry and movement of insects. Consequently, these design features of the traditional storage facilities all aim to control the development of insects without the use of chemicals. There different traditional storage structure used for grains which was list out in the Table 2, The effectiveness of these traditional storage facilities points to the need to incorporate traditional technology into present storage facilities for sustainability.

**Table 2. Traditional and Modern Grain storage facilities used for Post-Harvest Management**

S. No	Storage Structure	Construction Design	Commodities Stored	Capacity	Remarks
1	Bamboo Structures	Constructed from bamboo woven into a cylindrical shape with a wider base and narrower opening at the top	Paddy, wheat, sorghum	~500 kg	Average lifespan is 4-5 years. Insect infestation may cause about 5% weight loss in paddy and up to 15% in sorghum.
2	Mud / Earthen Structures	Prepared using a mixture of clay, straw, and cow dung in a ratio of 3:3:1. The structures are sun-dried and later hardened by burning	Paddy, wheat, sorghum, oilseeds, pulses	5-10 quintals	Service life ranges from 8-10 years. Cracks may develop during rainy seasons, allowing moisture entry and leading to insect and mould infestation.
3	Wooden Storage Structures	Built using locally available wood, usually coated with protective paint. An inlet opening (~30 × 20 cm) is provided at the top and an outlet (~30 × 15 cm) at the bottom for grain discharge.	Paddy	~10 quintals	Lifespan about 15-20 years. However, these structures are not airtight and do not prevent moisture entry effectively.
4	Brick Storage Structures	Permanent rectangular structures built with bricks using cement or lime mortar, often integrated with the house. Walls are typically 40-50 cm thick, with a top inlet (50 × 50 cm) and bottom outlet (15 × 15 cm).	Paddy, wheat, sorghum	25-30 quintals	Durable for 25-30 years. Construction cost is relatively high and protection against insects and moisture is limited.
5	Underground Storage Pits	Circular pits ranging from 100-400 cm depth, with neck diameter 50-100 cm and bottom diameter 250-300 cm. Interior surfaces are lined with straw or husk before filling, and sealed with straw, stones, and mud.	Cereals	100-200 quintals	Provides good protection from insects. However, seed viability may decrease, and grain handling is difficult, making this method less common today.
6	Storage Using Plant Materials	Includes storage bins or containers made from agricultural materials such as paddy straw ropes, stems of Vitex or pigeon pea, and bottle gourd shells. Often plastered with mud and cow dung.	Paddy, cereals, pulses	2 kg - 100 quintals (depending on structure)	Mostly temporary storage systems. Not resistant to insects or rodents and suitable mainly for storing small quantities of seeds.
7	Corrugated Galvanized Iron (GI) Sheet Structures	Cylindrical bins formed by vertically assembling GI sheets (~3 m height) with overlapping edges secured by bolts. Covered with plain GI or MS sheets on top.	Various grains	Variable	Generally used for temporary grain storage.
8	Hessian (Jute) Bags	Made from woven jute fibres. These bags are biodegradable and environmentally friendly. Often treated chemically to improve resistance to moisture and decay.	Rice, wheat, pulses and other grains	90-95 kg per bag	After treatment, bags become rot-resistant and can tolerate sunlight and moisture for longer storage periods.
9	Gunny Bags	Low-cost sacks made from jute or burlap fibers; modern versions may also use polypropylene.	Rice, pulses, vegetables	50-100 kg	Natural fibre bags are eco-friendly, breathable, non-toxic, and help maintain freshness by allowing air circulation.
10	IRRI Super Bag	A hermetic, reusable plastic storage bag designed to prevent entry of air, moisture, insects, and rodents.	Rice	Variable	When properly sealed, it allows safe seed storage for 9-12 months while maintaining germination potential.

**7. Research Gaps and Challenges in Scaling Traditional Practices**

Despite the effectiveness of these methods, they have also been subjected to a number of challenges which have been limiting their scale. Among these gaps in traditional methods-based research is the factor of non-standardization. Among traditional methods, non-standardization in terms of form, dosage, and application rate prevails. This is limiting the development of integrated guidelines for traditional methods and their incorporation in post-harvesting.

The challenges associated with the optimization of dosage, shelf life, and consistency of performance are also contributing factors for scalability challenges. Botanical and inert ingredients are inconsistent in performance depending on the plant types and shelf life.

Limited adoption of this approach by farmers is one main issue, and support from policy is another. This approach is perceived as old technology or technology that is less efficient, compared to chemical pesticides, and is not discussed or addressed at all. It is a need of the hour to respond to this gap by doing validation of this approach for its mainstreaming.

**8. Implications for Sustainable Food Security and Policy**

The extensive use of conventional insect control practices can be of immense use from the point of view of environmental and health advantages, including the reduction of chemical residues in food and the level of contamination in the environment. The use of conventional insect control practices will ensure the use of safe, eco-friendly, and biodegradable storage systems, as they are in line with concepts of sustainable agriculture.

Therefore, the effectiveness of these methods in ensuring the safety of the grains and pulses in post-harvesting activities will result in contributions to food security, which is a situation whereby people have access to adequate amounts of safe and healthy foods. These methods will, therefore, be effective, contributing to support for the One Health approach, which will reduce the risks of chemical exposure related to both humans and animals, while maintaining the ecosystem.

In the context of the formulation of policies, the emphasis on the incorporation of these scientifically proven traditional practices by extension services and national storage guidelines will ensure the empowerment of farmers along with better adoption and a safer food system. It is vital to advocate and encourage research, standardization, and capacity building programs for these cost-effective and traditional practices.

**9. Conclusion**

Traditional methods of handling insects in agriculture have provided a much-needed way of ensuring sustainability in insect management. Some of the key points revolve around the use of botanicals, oils, inert, and traditional storage structures, among others, in post-harvest insect management. However, these methods will be able to fully attain their potential through scientific research into these methods. The integration of traditional methods with modern technology in post-harvest handling will be able to provide a platform for the One Health approach. This will be essential in providing a clear vision for the future of insect management, with the knowledge of the past utilized to its maximum potential in ensuring effective modern practices.

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