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# Traditional Ayurvedic Strategies for Stored Grain Protection: A Scientific Review

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**Abstract**

Stored grain losses caused by insect pests, fungi, rodents, and microbial contamination pose a significant challenge to global food security, resulting in substantial post-harvest losses and economic damage. Although synthetic fumigants and chemical pesticides have been widely employed for grain preservation, their prolonged use has led to pesticide resistance, environmental pollution, toxic residues, and adverse effects on human health. These limitations have renewed scientific interest in traditional, eco-friendly grain protection strategies. Ayurveda, particularly the principles described in **Vrikshayurveda** and other classical agricultural texts, documents numerous botanical and natural approaches for preserving stored grains using medicinal plants, herbal fumigation, plant-derived powders, oils, and cow-based formulations. The present review aims to critically evaluate traditional Ayurvedic strategies for stored grain protection and examine their scientific relevance in the context of modern post-harvest pest management. A comprehensive literature review was conducted using classical Ayurvedic texts, including *Surapala's Vrikshayurveda*, *Krishi-Parashara*, *Kashyapiya Krishi Sukti*, and *Brihat Samhita*, together with contemporary scientific literature retrieved from PubMed, Scopus, Web of Science, Google Scholar, and other databases. The review highlights the role of medicinal plants such as *Acorus calamus*, *Achyranthes aspera*, *Azadirachta indica*, *Embelia ribes*, *Curcuma longa*, *Vitex negundo*, and *Allium sativum*, whose bioactive phytochemicals exhibit insecticidal, antifungal, repellent, and grain-protective properties. Contemporary scientific evidence supports many traditional claims and demonstrates the potential of these botanical formulations as environmentally safe alternatives to synthetic grain protectants. However, further research is required to standardize formulations, validate their efficacy under field conditions, and facilitate their commercialization. Integrating Ayurvedic knowledge with modern post-harvest technologies may contribute significantly to sustainable grain storage, food security, and environmentally responsible pest management.

**Keywords:** Vrikshayurveda, Stored Grain Protection, Botanical Pesticides, Medicinal Plants, Post-Harvest Management, Sustainable Agriculture

## 1. Introduction

Stored grains are essential for ensuring global food security, nutritional stability, and economic sustainability. Cereals, pulses, and oilseeds are commonly stored for prolonged periods to meet domestic consumption, seed requirements, and commercial demands. However, a considerable proportion of

harvested grains is lost during storage due to infestation by insects, fungal contamination, rodents, mites, and unfavorable environmental conditions. These post-harvest losses reduce grain quantity, nutritional quality, germination potential, and market value, thereby posing a significant challenge to agricultural productivity and food availability (Food and Agriculture Organization [FAO], 2021; Hodges et al., 2011). In developing countries, inadequate storage infrastructure and ineffective pest management practices further aggravate these losses, affecting both farmers and consumers (Boxall, 2001).

Among the various factors responsible for post-harvest deterioration, insect pests constitute one of the most serious threats to stored grains. Species such as *Callosobruchus chinensis*, *Callosobruchus maculatus*, *Sitophilus oryzae*, *Rhyzopertha dominica*, and *Tribolium castaneum* cause extensive damage by feeding on grains, reducing seed viability, contaminating food with insect fragments and excreta, and promoting secondary microbial infestation (Phillips & Throne, 2010). Fungal pathogens belonging to the genera *Aspergillus*, *Penicillium*, and *Fusarium* further compromise grain quality by causing spoilage and producing mycotoxins that pose serious health risks to humans and livestock (Magan et al., 2011; Pitt & Hocking, 2009). Consequently, effective grain preservation has become an indispensable component of post-harvest management.

Modern grain protection strategies primarily rely on synthetic insecticides and fumigants such as phosphine and other chemical protectants. Although these agents have contributed significantly to reducing storage losses, their indiscriminate and prolonged use has resulted in several undesirable consequences, including the development of pesticide resistance, contamination of food grains, environmental pollution, destruction of beneficial organisms, and occupational health hazards (Nayak et al., 2020; Pimentel & Burgess, 2014). Increasing consumer preference for residue-free food products, together with growing environmental concerns and stricter regulatory policies, has accelerated the search for safe, biodegradable, and sustainable alternatives to chemical grain protectants (Isman, 2020).

Traditional agricultural knowledge offers valuable insights into environmentally friendly methods of grain preservation. In India, Ayurveda and its allied agricultural sciences describe numerous practices for protecting harvested produce using naturally available resources. Among these, **Vrikshayurveda**, the ancient science of plant health, provides systematic guidelines for cultivation, crop protection, storage, and preservation of agricultural produce (Sadhale, 1996; Nene, 2006). Classical treatises such as *Surapala's Vrikshayurveda*, *Krishi-Parashara*, *Kashyapiya Krishi Sukti*, and *Brihat Samhita* describe the use of medicinal plants, herbal fumigation, botanical powders, plant-derived oils, fermented preparations, and cow-based products for protecting stored grains against insects and microbial spoilage (Majumdar, 1935; Gopal, 2000). These practices were developed with an emphasis on ecological balance, sustainability, and the use of renewable natural resources.

Several medicinal plants described in Ayurvedic literature possess well-documented biological activities that support their traditional use in grain preservation. *Acorus calamus* (Vacha) contains β-asarone and other volatile constituents with insecticidal and fumigant properties (Koul et al., 2008). *Azadirachta indica* (Nimba) is rich in azadirachtin and related limonoids that interfere with insect feeding, growth, and reproduction (Isman, 2006). *Achyranthes aspera* (Apamarga), *Embelia ribes* (Vidanga), *Curcuma longa* (Haridra), *Vitex negundo* (Nirgundi), and *Allium sativum* (Lashuna) possess diverse phytochemicals exhibiting insecticidal, antifungal, antibacterial, repellent, oviposition-deterrent, and grain-protective activities (Pavela & Benelli, 2016; Tripathi et al., 2009). These botanical resources have attracted increasing scientific interest because they offer broad-spectrum biological activity while minimizing environmental hazards associated with synthetic pesticides (Regnault-Roger et al., 2012).

Recent advances in phytochemistry, microbiology, entomology, and post-harvest technology have provided substantial scientific evidence supporting many traditional Ayurvedic practices for stored grain protection. Experimental studies have demonstrated that botanical formulations prepared from medicinal plants effectively reduce insect infestation, inhibit fungal growth, preserve seed viability, and improve storage quality (Copping & Menn, 2000; Isman, 2020). Despite these encouraging findings, the available information remains scattered across classical texts and modern scientific literature. Variations in plant materials, methods of preparation, dosage, and evaluation protocols have also limited the standardization and large-scale adoption of these botanical grain protectants (Sharma & Nathani, 2025).

Considering the increasing emphasis on sustainable agriculture, organic food production, and environmentally responsible pest management, there is a growing need to systematically evaluate traditional Ayurvedic grain preservation strategies using contemporary scientific evidence. Such an approach may facilitate the development of standardized, safe, and effective botanical formulations that complement modern post-harvest technologies and reduce dependence on synthetic pesticides (Meshram & Meshram, 2019).

The present review aims to compile and critically analyze the traditional Ayurvedic strategies employed for stored grain protection, summarize the available scientific evidence supporting their efficacy, discuss the probable mechanisms responsible for their grain-protective activities, and highlight their potential applications, limitations, and future prospects in sustainable post-harvest management.

## 2. Aim and Objectives

### Aim

To critically review the traditional Ayurvedic strategies for stored grain protection and evaluate their scientific relevance in the context of modern post-harvest pest management and sustainable agriculture.

### Objectives

1. To compile and summarize traditional grain protection practices described in Ayurvedic and Vrikshayurveda literature.
2. To review medicinal plants and botanical formulations traditionally employed for the protection of stored grains against insect pests and microbial spoilage.
3. To critically evaluate the available scientific evidence regarding the insecticidal, repellent, antifungal, antibacterial, and grain-protective activities of these medicinal plants.
4. To discuss the probable mechanisms of action and phytochemical constituents responsible for their grain-protective effects.
5. To identify the advantages, limitations, and research gaps associated with Ayurvedic botanical grain protectants.
6. To explore the potential integration of traditional Ayurvedic knowledge with contemporary post-harvest management practices for developing safe, eco-friendly, and sustainable grain protection strategies.

### Research Question

**Can traditional Ayurvedic grain protection strategies, supported by contemporary scientific evidence, provide effective, safe, and sustainable alternatives to synthetic pesticides for stored grain preservation?**

## 3. Materials and Methods

### 3.1 Study Design

The present study was conducted as a narrative review to compile, evaluate, and synthesize information on traditional Ayurvedic strategies for stored grain protection. Evidence was collected from classical Ayurvedic literature and contemporary scientific publications to provide a comprehensive overview of traditional grain preservation practices and their scientific validation.

### 3.2 Literature Search Strategy

A comprehensive literature search was performed using electronic databases, including **PubMed**, **Scopus**, **Web of Science**, **Google Scholar**, **ScienceDirect**, and **SpringerLink**. Classical Ayurvedic information was obtained from authoritative texts such as *Vrikshayurveda* of Surapala, *Krishi-Parashara*, *Kashyapiya Krishi Sukti*, *Brihat Samhita*, *Charaka Samhita*, *Sushruta Samhita*, *Ashtanga Hridaya*, *Bhavaprakasha Nighantu*, and other relevant Ayurvedic compendia.

The search included studies published in English using combinations of the following keywords: **"stored grain protection," "post-harvest pest management," "Ayurveda," "Vrikshayurveda," "medicinal plants," "botanical pesticides," "grain storage," "biopesticides," "essential oils," "herbal fumigation," "Acorus calamus," "Azadirachta indica," "Achyranthes aspera," "Embelia ribes," "Curcuma longa," "Vitex negundo,"** and **"Allium sativum."**

### 3.3 Inclusion Criteria

The review included:

- Original research articles evaluating medicinal plants for stored grain protection.
- Review articles related to botanical pesticides and post-harvest pest management.
- Classical Ayurvedic and Vrikshayurveda texts describing grain preservation practices.
- Studies reporting insecticidal, repellent, oviposition-deterrent, fumigant, antifungal, antibacterial, or grain-protective activities of medicinal plants.
- Publications available in English.

### 3.4 Exclusion Criteria

The following publications were excluded:

- Studies unrelated to stored grain protection.
- Articles lacking sufficient methodological details or scientific evidence.
- Conference abstracts, editorials, opinion articles, and unpublished reports.
- Duplicate publications retrieved from multiple databases.

### 3.5 Data Extraction and Synthesis

Relevant information was extracted independently from the selected literature, including the medicinal plant investigated, botanical family, plant part used, traditional Ayurvedic references, phytochemical constituents, target storage pests or microorganisms, reported biological activities, mechanisms of action, and major findings. The collected evidence was critically analyzed and organized into thematic sections to compare traditional knowledge with contemporary scientific research. Areas of agreement, limitations, and future research priorities were identified to provide an integrated perspective on Ayurvedic grain protection strategies.

**Table 1. Summary of the literature review methodology**

| Component | Description |
|---|---|
| **Study design** | Narrative review |

| | |
|---|---|
| **Information sources** | PubMed, Scopus, Web of Science, Google Scholar, ScienceDirect, SpringerLink, classical Ayurvedic texts |
| **Language** | English |
| **Literature included** | Original research articles, review articles, and classical Ayurvedic literature |
| **Main search terms** | Stored grain protection, Ayurveda, Vrikshayurveda, medicinal plants, botanical pesticides, post-harvest management |
| **Data extracted** | Plant name, plant part, phytochemicals, biological activity, target pest, mechanism of action, key findings |
| **Method of synthesis** | Thematic narrative synthesis |

For your **IJFMR review article**, the **Results and Discussion** should not present experimental data. Instead, it should **synthesize the available evidence** from classical Ayurvedic literature and modern scientific studies. Organizing this section with subheadings and summary tables makes it easier to follow.

## 4. Results and Discussion

The reviewed literature demonstrates that Ayurvedic texts and Vrikshayurveda describe several natural strategies for preserving stored grains and protecting them against insect infestation and microbial deterioration. These traditional practices emphasize preventive measures, the use of medicinal plants, botanical formulations, herbal fumigation, and proper storage management. Contemporary scientific studies have validated many of these practices by demonstrating insecticidal, repellent, oviposition-deterrent, fumigant, antifungal, and antibacterial activities of medicinal plants commonly described in classical literature. The findings suggest that Ayurvedic grain protection strategies have considerable potential for integration into sustainable post-harvest management systems.

### 4.1 Classical Ayurvedic Concepts of Stored Grain Protection

Ancient Indian agricultural literature recognized the importance of protecting harvested grains from spoilage and pest infestation. Classical works such as *Vrikshayurveda* of Surapala, *Krishi-Parashara*, *Kashyapiya Krishi Sukti*, and *Brihat Samhita* describe several preventive measures, including thorough drying of grains before storage, cleaning storage structures, maintaining low moisture levels, periodic inspection, herbal fumigation, and the use of plant-based powders, leaves, oils, and ash. These measures were intended to preserve grain quality, maintain seed viability, and prevent losses caused by insects and microorganisms.

Unlike modern pest management, which often relies on synthetic chemicals, Ayurvedic practices emphasized ecological balance and the use of biodegradable natural materials that were locally available and considered safe for humans and the environment.

**Table 2. Traditional Ayurvedic strategies for stored grain protection**

| Traditional practice | Purpose | Probable scientific basis |
|---|---|---|
| **Sun drying of grains** | Moisture reduction | Inhibits insect development and fungal growth |
| **Cleaning of storage structures** | Removal of contaminants | Reduces initial pest population |

| | | |
|---|---|---|
| **Herbal fumigation** | Insect repellence | Volatile phytochemicals affect insects |
| **Botanical powders** | Grain protection | Contact toxicity and oviposition deterrence |
| **Plant-derived oils** | Protective coating | Reduces insect feeding and egg laying |
| **Cow-based products** | Preservation and sanitation | Antimicrobial properties reported in some studies |

### 4.2 Medicinal Plants Used in Stored Grain Protection

Several medicinal plants described in Ayurveda possess biological activities relevant to stored grain protection. Their efficacy is attributed to bioactive phytochemicals such as alkaloids, terpenoids, phenolics, flavonoids, saponins, and essential oils.**Acorus calamus (Vacha)**

*Acorus calamus* contains volatile constituents, particularly β-asarone, α-asarone, and other phenylpropanoids, which exhibit insecticidal, fumigant, and repellent activities. Studies have demonstrated its effectiveness against *Callosobruchus chinensis*, *Sitophilus oryzae*, and *Tribolium castaneum*. The essential oil interferes with insect respiration, feeding, and reproduction, thereby reducing grain infestation.

**Azadirachta indica (Nimba)**

Neem is one of the most extensively studied botanical pesticides. Azadirachtin and related limonoids act as feeding deterrents, insect growth regulators, oviposition inhibitors, and repellents. Neem leaf powder, seed kernel powder, and neem oil have been successfully used to protect cereals and pulses during storage.

**Achyranthes aspera** (**Apamarga**)

*Achyranthes aspera* possesses insecticidal, repellent, and antimicrobial properties. Phytochemicals such as saponins, alkaloids, and flavonoids contribute to its protective effects against stored-grain insects. Traditional use includes powdered plant material and herbal formulations for grain preservation.

**Embelia ribes (Vidanga)**

Vidanga is well known in Ayurveda for its **Krimighna** (anti-parasitic) property. Embelin, the principal bioactive constituent, exhibits insecticidal and antimicrobial activity. Although evidence specific to stored-grain pests is comparatively limited, available studies indicate promising grain-protective potential.

**Curcuma longa (Haridra)**

Turmeric contains curcuminoids and volatile oils with antimicrobial, antifungal, antioxidant, and insect-repellent activities. Turmeric powder has traditionally been mixed with stored grains to reduce microbial contamination and insect damage.

**Vitex negundo (Nirgundi)**

The leaves of *Vitex negundo* contain essential oils and flavonoids possessing insecticidal, repellent, and fumigant properties. Dried leaves placed in storage containers have traditionally been used to repel insect pests.

**Allium sativum (Lashuna)**

Garlic contains sulfur-containing compounds, particularly allicin, which exhibit insecticidal, antibacterial, and antifungal activities. Garlic extracts and essential oils have shown inhibitory effects against several storage insects and fungal pathogens.

**Table 3. Medicinal plants used for stored grain protection**

| Plant | Major phytochemicals | Reported activity | Target pests |
|---|---|---|---|
| ***Acorus calamus*** | β-Asarone, essential oils | Insecticidal, fumigant, repellent | *Callosobruchus*, *Sitophilus*, *Tribolium* |
| ***Azadirachta indica*** | Azadirachtin, limonoids | Feeding deterrent, growth regulator | Wide range of storage insects |
| ***Achyranthes aspera*** | Saponins, alkaloids | Repellent, insecticidal | Pulse beetles, storage insects |
| ***Embelia ribes*** | Embelin | Insecticidal, antimicrobial | Storage pests |
| ***Curcuma longa*** | Curcumin, turmerones | Antifungal, antimicrobial | Storage fungi and insects |
| ***Vitex negundo*** | Essential oils, flavonoids | Repellent, fumigant | Storage insects |
| ***Allium sativum*** | Allicin | Antifungal, insecticidal | Insects and fungi |

### 4.3 Proposed Mechanisms of Grain Protection

The reviewed evidence indicates that Ayurvedic medicinal plants protect stored grains through multiple mechanisms:

- Repelling insects through volatile compounds.
- Inhibiting feeding and oviposition.
- Causing contact and fumigant toxicity.
- Disrupting insect growth and reproduction.
- Preventing fungal and bacterial contamination.
- Preserving grain quality and seed viability during storage.

The presence of multiple bioactive constituents enables these plants to exert broad-spectrum biological effects, thereby reducing the likelihood of resistance compared with single-target synthetic pesticides.

### 4.4 Scientific Validation and Current Research

Numerous laboratory investigations have confirmed the efficacy of Ayurvedic medicinal plants against major storage pests. Essential oils from *Acorus calamus*, neem derivatives, turmeric extracts, garlic oil, and *Vitex negundo* have demonstrated significant reductions in insect survival, oviposition, adult emergence, grain damage, and fungal growth. Nevertheless, most available studies have been conducted under controlled laboratory conditions. Limited information is available regarding formulation standardization, long-term storage performance, large-scale field validation, residue analysis, and economic feasibility.

### 4.5 Research Gaps and Future Perspectives

Although encouraging evidence supports the grain-protective potential of Ayurvedic botanicals, several gaps remain:

- Lack of standardized botanical formulations and dosage recommendations.
- Limited multicentric field trials under diverse storage conditions.
- Insufficient quality control and phytochemical standardization.
- Inadequate safety evaluations and residue studies.
- Limited commercialization and technology transfer.

Future research should focus on developing standardized formulations, validating efficacy under practical storage conditions, identifying bioactive compounds responsible for insecticidal activity, and integrating Ayurvedic grain protection strategies with modern post-harvest technologies. Advances in phytochemistry, nanotechnology, and formulation science may further improve the stability, efficacy, and scalability of botanical grain protectants.

## 5. Conclusion

Traditional Ayurvedic literature provides a rich repository of knowledge on the preservation of stored grains through the use of medicinal plants, botanical formulations, herbal fumigation, and appropriate storage practices. The concepts described in *Vrikshayurveda* and other classical texts emphasize preventive, eco-friendly, and sustainable approaches to post-harvest grain protection, many of which remain relevant in the present era of sustainable agriculture.

The evidence reviewed in this article indicates that medicinal plants such as *Acorus calamus*, *Azadirachta indica*, *Achyranthes aspera*, *Embelia ribes*, *Curcuma longa*, *Vitex negundo*, and *Allium sativum* possess significant insecticidal, repellent, fumigant, antifungal, and antimicrobial activities. These properties support their traditional use in protecting stored grains against insect pests and microbial spoilage. Compared with synthetic pesticides, Ayurvedic botanical protectants offer several advantages, including biodegradability, lower environmental impact, reduced risk of harmful chemical residues, and compatibility with organic and integrated pest management systems.

Despite encouraging scientific evidence, the widespread adoption of Ayurvedic grain protection strategies is limited by the lack of standardized formulations, optimized dosage protocols, quality control measures, large-scale field validation, and regulatory guidelines. Most published studies have been conducted under laboratory conditions, highlighting the need for well-designed field trials and multidisciplinary research to establish efficacy, safety, shelf life, and commercial feasibility under diverse storage environments.

Future investigations should focus on phytochemical standardization, identification of bioactive compounds, development of stable and user-friendly formulations, evaluation of synergistic combinations of medicinal plants, and integration of traditional knowledge with modern post-harvest technologies. Collaborative efforts involving Ayurveda, agricultural sciences, entomology, phytochemistry, microbiology, and food technology will be essential for translating these traditional practices into scientifically validated and commercially viable grain protection solutions.

In conclusion, Ayurvedic strategies for stored grain protection represent a promising and sustainable alternative to conventional chemical pesticides. Their scientific validation and integration into contemporary post-harvest management can contribute to reducing storage losses, improving food safety, supporting environmentally responsible agriculture, and preserving the valuable traditional knowledge of **Vrikshayurveda** for future generations.

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