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Exploring various natural and organic approaches for storage and preservation of food grains

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Abstract
The utilization of herbs for the preservation of food grains represents a traditional and sustainable approach to extending the shelf life of essential staples. Throughout history, people have relied on plant materials to safeguard field crops and stored goods from insect damage. Interestingly, many of these plants have also played significant roles in traditional medicine among local communities. Whether collected from the wild or intentionally cultivated, leaves, roots, twigs, and flowers have been combined with various commodities to act as protective agents against pests in different regions across the globe. Various storage structures like aerial structures, underground pits, gourds, bamboo baskets, straw mats are used for storage across villages. While for preservation of food grains, range of herbs including turmeric, basil, marjoram, anise, cumin, chili pepper, and coriander, as well as extracts from neem and Siam weed, alongside tobacco leaves and vegetable oil, are commonly utilized as effective agents. The duration of storage and preservation varies depending on factors such as the type of material and herb used, storage conditions, and initial grain quality. However, when stored properly in airtight containers with adequate ventilation, preserved grains can maintain their quality for several months to a year. The efficiency of herb-based preservation techniques lies in their ability to not only extend the shelf life of food grains but also enhance their flavor and nutritional value.

Keywords: Food grains, herbs, pest, preservation, shelf life, traditional

Introduction
Food grain production in India plays a vital role in sustaining the country's agricultural sector and ensuring food security for its vast population. India, with over 70% of its population relying on agriculture, has significantly increased its pulse and grain production in recent decades. However, despite advancements in technology, post-harvest losses remain a significant challenge, accounting for approximately 10% of crop damage, with storage-related losses contributing to about 6% of this total. Insufficient storage and processing facilities are causing considerable damage to food grains post-harvest. Additionally, fluctuations in climatic events such as floods, droughts, and irregular temperature and rainfall patterns could significantly affect agricultural production (Arun *et al*., 2017) [1]. Post-harvest losses due to insect and pest infestation pose a serious threat to the quality and quantity of stored grains in India. Insects like bruchids, rice weevil, lesser grain borer, granary weevil, warehouse moth are major pests that infest stored grain pulses and cereals, causing substantial damage. These pests penetrate mature grains during storage, leading to quality deterioration and significant economic losses. Chemical insecticides have been traditionally used to control these pests; however, the adverse health effects associated with synthetic chemicals have raised concerns, prompting the exploration of alternative, safe, and sustainable pest management practices. In response to the persistent challenge of insect infestation jeopardizing stored grain supplies, Indian farmers have ingeniously embraced a holistic approach merging traditional herbal practices with modern methodologies for preservation. This symbiotic fusion draws upon centuries-old wisdom passed down through generations, intertwining it with cutting-edge techniques to fortify the resilience of stored ecosystems. By synergizing ancient remedies with scientific advancements, farmers endeavor to mitigate the detrimental effects of pests on grain reserves.

This harmonious coalescence not only preserves the nutritional integrity of the grains but also sustains the livelihoods of farming communities, ensuring food security for present and future generations.

Tradition methods for storage of food grains

Traditional methods of food grain storage have been crucial for preserving grains for centuries, ensuring food security and sustainability (Hall, 1970) [3]. Every grain storage method or structure fundamentally aims to protect grains from insects and rodents, as well as prevent spoilage caused by microbial activity The age-old techniques for storing and preserving grains have been in practice since ancient times. These methods were cultivated within communities and passed down from one generation to the next (Natarajan and Santha, 2006) [9]. Some of the traditional methods for food grain preservation are as follows: -

1. **Aerial Storage in Tied Bundles:** Hanging bundles of grains in well-ventilated areas helps prevent moisture buildup and pest infestation. This method utilizes vertical space efficiently, keeping grains off the ground and safe from pests. It's a simple yet effective way to preserve grains without the need for elaborate storage structures.
2. **Underground Pits:** Digging pits in the ground provides a natural and stable environment for grain storage. The cool temperature of the earth helps maintain grain quality and prevents spoilage. This method has been used for centuries in various cultures and regions, demonstrating its reliability and effectiveness.

Fig 1: Underground pit storage in Andra Pradesh (Source: News18)

3. **Earthen Bins or Pots:** Clay pots or bins offer a breathable and natural environment for grain storage. The porous nature of clay allows air circulation, preventing mold growth and preserving grain freshness. Earthen containers also help regulate moisture levels, ensuring grains remain dry and free from spoilage.
4. **Mud Rhombus:** Constructing rhombus-shaped mud structures provides protection from pests and environmental factors. These structures offer insulation and stability, maintaining optimal conditions for grain preservation. Mud rhombuses are a traditional storage solution in many agricultural communities, reflecting their practicality and efficiency.
5. **Wooden Boxes:** Wooden boxes with proper ventilation are ideal for storing grains. Air circulation prevents moisture buildup and mold growth, preserving grain quality. Wooden boxes are durable and versatile, making them suitable for long-term grain storage in various environments.
6. **Gourds:** Dried gourds serve as natural and breathable containers for storing grains. Gourds offer protection from pests while allowing air circulation, maintaining grain freshness. This eco-friendly storage option is lightweight and easy to handle, making it a popular choice in traditional grain storage practices.

Fig 2: Gourds for seed storage (Source: TNAU Agritech portal)

7. **Bamboo Baskets:** Bamboo baskets provide air circulation and protection from pests, ensuring grain quality. The natural strength and flexibility of bamboo make it an excellent material for grain storage containers. Bamboo baskets are lightweight and durable, making them suitable for both short-term and long-term storage needs.
8. **Thatched Granaries:** Granaries with thatched roofs offer insulation and protection from moisture. Thatched roofs provide ventilation while shielding grains from direct sunlight and rain. This traditional storage method has been used for centuries and remains effective in preserving grain quality.
9. **Jute Bags:** Storing grains in jute bags allows for air circulation while protecting against pests and mold. Jute is a breathable material that helps maintain grain freshness and quality. Jute bags are affordable and biodegradable, making them an eco-friendly choice for grain storage.
10. **Clay Pots:** Clay pots provide a cool and breathable environment for grain storage. The porous nature of clay allows air circulation, preventing moisture buildup and mold growth. Clay pots are durable and aesthetically pleasing, making them a popular choice for traditional grain storage methods.
11. **Cow Dung Coating:** Coating grain containers with cow dung acts as a natural insect repellent and helps regulate temperature. Cow dung has antimicrobial properties that inhibit pest infestation and spoilage. This traditional method of grain preservation is cost-effective and environmentally friendly.
12. **Leaf Wrapping:** Wrapping grains in leaves such as banana leaves provides short-term protection and preserves freshness. Leaves offer a natural barrier against pests and moisture, keeping grains safe during transport or temporary storage. Leaf wrapping is a simple yet effective way to preserve grains in traditional farming communities.
13. **Straw Matting:** Grains placed on straw mats benefit from air circulation and avoid direct contact with the ground, preventing moisture buildup and pest infestation. This method is simple yet effective, particularly in temporary storage situations or for small quantities of grains.

Fig 3: Paddy straw storage structure (Source: TNAU Agritech portal)

14. **Stone Containers:** Stone containers offer a cool and pest-resistant environment ideal for long-term grain preservation. The density of stone provides insulation against temperature fluctuations, maintaining stable storage conditions. This traditional method is durable and well-suited for storing grains in regions with harsh climates or where pest infestation is a concern.

These traditional methods of food grain storage showcase the ingenuity of ancient cultures in preserving grains effectively without the need for modern technology. Each method reflects a deep understanding of environmental conditions and the importance of maintaining grain quality for sustenance and future use.

Traditional herbs as a source of grain preservation

In agriculture, storing grains is incredibly important and requires careful attention. One major challenge farmer's face is the damage caused by insect infestations. Despite their small size, these pests can wreak havoc on stored grains, leading to significant economic losses and food shortages.

Different types of insects contribute to grain storage losses, each with its own role in damaging the quality and quantity of stored grains. Some of the most common offenders include the Rice Weevil *(Sitophilus oryzae*), the Maize Weevil (*Sitophilus zeamais*), and the Lesser Grain Borer (*Rhyzopertha dominica*). Together, these insects are responsible for causing a considerable percentage of grain damage globally, estimated to be as high as 20-30%.

The damage inflicted by these insects primarily occurs through their feeding activities, which involve tunnelling into grains, consuming the kernels, and contaminating the produce with their waste. It's crucial to understand the behaviour and impact of these insects to implement effective storage management practices. This helps mitigate losses and ensures food security for communities that rely on stored grains.

Grain preservation has been a critical aspect of human civilization since ancient times, with various methods employed to ensure long-term storage and food security. Traditional herbs have played a significant role in this process, offering natural solutions for preserving grains without the need for synthetic chemicals.

Fig 4: Grains infested by rice weevil

Fig 5: Grains infested by lesser grain borer

Some of the commonly used herbs are as follows

1. ***Annona muricata*** **(Sour SOP.)**
   - **Chemical Compounds:** Alkaloids, flavonoids, tannins, and saponins.
   - **Mechanism:** The methanol extract of *Annona muricata* acts as a natural biocontrol agent against grain pests due to its alkaloids and flavonoids, which have insecticidal properties.
   - **Example:** *Annona muricata* extract can be used to protect stored grains like rice and maize from pests like the maize weevil.
2. ***Acanthus montanus***
   - **Chemical Compounds:** Alkaloids, saponin, tannin, and flavonoid.
   - **Mechanism:** The plant powder of *Acanthus montanus* contains compounds that act as protectants against grain pests by repelling insects and inhibiting their growth.
   - **Example:** *Acanthus montanus* plant powder can be used to preserve sorghum and millet from infestations by pests like the lesser grain borer.
3. ***Zingiber officinale*** **(Ginger)**
   - **Chemical Compounds:** Contains various bioactive compounds.
   - **Mechanism:** Ginger plant powder acts as a natural insect repellent due to its strong aroma and compounds that deter pests from infesting stored grains.
   - **Example:** Sprinkling ginger powder in grain storage areas can help prevent infestations by pests like the rice weevil.
4. ***Piper corcovadensis***
   - **Chemical Compounds:** Phenylpropanoid, monoterpenes α-pinene, and terpinolene.
   - **Mechanism:** The essential oil extracted from *Piper corcovadensis* leaves acts as a potent insecticide, disrupting pest behavior and preventing damage to stored grains.
   - **Example:** Using *Piper corcovadensis* leaf essential oil

can protect wheat and barley from pests like the granary weevil.

5. ***Alchornea cordifolia***
   - **Chemical Compounds:** Contains bioactive compounds with insecticidal properties.
   - **Mechanism:** *Alchornea cordifolia* plant powder serves as a natural pesticide by repelling insects and inhibiting their reproductive cycle in stored grains.
   - **Example:** Utilizing *Alchornea cordifolia* powder can safeguard corn and beans from infestations by pests like the warehouse moth.
6. ***Lantana camara***
   - **Chemical Compounds:** Phytol, Pyrroline, Paromomycin, Pyrrolizin, 1-Eicosano.
   - **Mechanism:** *Lantana camara* plant powder and essential oil act as deterrents against grain pests by disrupting their feeding habits and life cycle.
   - **Example:** Applying *Lantana camara* extracts can protect pulses and legumes from damage caused by pests like the red flour beetle.
7. ***Lamium purpureum* (Purple Deadnettle)**
   - **Chemical Compounds:** Alkaloids, terpenoids, flavonoids, tannins, saponins, phytosteroids, phenolic compounds.
   - **Mechanism:** The plant powder of *Lamium purpureum* contains compounds that repel insects and inhibit their growth in stored grains.
   - **Example:** Using *Lamium purpureum* powder can help preserve oats and rye from infestations by pests like the lesser grain borer.
8. ***Cupressus macrocarpa* (Monterey Cypress)**
   - **Chemical Compounds:** Contains bioactive compounds with insecticidal properties.
   - **Mechanism:** *Cupressus macrocarpa* plant powder acts as a natural pesticide by creating an inhospitable environment for grain pests.
   - **Example:** Employing *Cupressus macrocarpa* powder can safeguard wheat and barley from damage caused by pests like the rice weevil.
9. ***Moringa oleifera* (Drumstick Tree)**
   - **Chemical Compounds:** Alkaloids, saponins, tannins, phenolic compounds, steroids, flavonoids, anthraquinones, phlobatannins, cardiac glycosides, terpenoids.
   - **Mechanism:** *Moringa oleifera* plant powder contains a diverse array of compounds that act as natural protectants against grain pests by repelling insects and inhibiting their development.
   - **Example:** Using *Moringa oleifera* powder can help preserve rice and sorghum from infestations by pests like the granary weevil.
10. ***Eucalyptus camaldulensis* (River Red Gum)**
    - **Chemical Compounds:** Contains bioactive compounds with insecticidal properties.
    - **Mechanism:** *Eucalyptus camaldulensis* plant powder serves as a natural pesticide by emitting volatile compounds that deter grain pests.
    - **Example:** Sprinkling *Eucalyptus camaldulensis* powder in storage areas can protect maize and wheat from damage caused by pests like the warehouse moth.
11. ***Tithonia diversifolia* (Mexican Sunflower)**
    - **Chemical Compounds:** Tannin, flavonoid, saponin, phenol, terpenoid, glucosides.
    - **Mechanism:** *Tithonia diversifolia* plant extracts contain compounds that disrupt pest behavior and inhibit their reproduction in stored grains.
    - **Example:** Using *Tithonia diversifolia* extracts can safeguard barley and oats from infestations by pests like the red flour beetle.
12. ***Azadirachta indica* (Neem)**
    - **Chemical Compounds:** Neem contains various bioactive compounds like azadirachtin, nimbin, and salannin.
    - **Mechanism:** Neem acts as a natural insect repellent and disrupts the growth and development of pests due to its compounds' insecticidal properties.
    - **Example:** Neem seed extracts have been used successfully to control infestations of pests like aphids and diamondback moths in crops like cabbage
13. ***Chromolaena odorata* (Siam Weed)**
    - **Chemical Compounds:** Siam Weed contains compounds like tannins, flavonoids, and saponins.
    - **Mechanism:** Siam Weed extracts act as botanical insecticides by repelling insects and inhibiting their reproductive cycle, reducing pest populations in stored grains.
    - **Example:** Siam Weed extracts have been effective in controlling pests like the diamondback moth and aphids in crops like cabbage, offering an environmentally friendly alternative to conventional insecticides.
14. ***Ocimum spp.* (Basil)**
    - **Chemical Compounds:** Basil contains essential oils like eugenol, linalool, and methyl chavicol.
    - **Mechanism:** The essential oils in basil act as natural insect repellents, deterring pests from stored grains and inhibiting their growth.
    - **Example:** Basil leaves can be dried and crushed to create a powder that helps protect grains like rice and wheat from infestations by pests like the rice weevil.
15. ***Cuminum cyminum* (Cumin)**
    - **Chemical Compounds:** Cumin contains bioactive compounds such as cuminaldehyde and cymene.
    - **Mechanism:** The compounds in cumin seeds have insecticidal properties that repel pests and prevent damage to stored grains.
    - **Example:** Cumin seeds can be ground into a powder and sprinkled in grain storage areas to deter pests like the granary weevil from infesting crops like barley and maize.
16. ***Capsicum annuum* (Chilli pepper)**
    - **Chemical Compounds:** Chili peppers contain capsaicin, which gives them their spicy flavor.
    - **Mechanism:** Capsaicin acts as a natural deterrent for insects due to its pungent nature, protecting stored grains from pest infestations.
    - **Example:** Crushed chili peppers can be sprinkled around grain storage areas to ward off pests like the red flour beetle from damaging crops like sorghum and millet.
17. ***Curcuma longa* (Turmeric)**
    - **Chemical Compounds:** Turmeric contains curcumin, a bioactive compound with antimicrobial properties.
    - **Mechanism:** Curcumin in turmeric acts as a natural preservative by inhibiting the growth of fungi and bacteria that can spoil stored grains.
    - **Example:** Turmeric powder can be mixed with grains like lentils and beans to prevent microbial contamination during storage, ensuring their quality

and longevity.

18. ***Origanum majorana*** **(Marjoram)**
    - **Chemical Compounds:** Marjoram contains compounds like terpinen-4-ol and linalool.
    - **Mechanism:** The aromatic compounds in marjoram act as natural insect repellents, protecting stored grains from pests like the warehouse moth.
    - **Example:** Dried marjoram leaves can be placed in grain storage containers to deter insects and maintain the quality of crops like oats and rye.
19. ***Pimpinella anisum*** **(Anise)**
    - **Chemical Compounds:** Anise seeds contain anethole, which gives them their characteristic flavor.
    - **Mechanism:** Anethole acts as a natural insecticide, repelling pests from stored grains and preventing damage.
    - **Example:** Anise seeds can be crushed and sprinkled around grain storage areas to deter insects like the lesser grain borer from infesting crops such as wheat and barley.
20. ***Coriandrum sativum*** **(Coriander)**
    - **Chemical Compounds:** Coriander contains bioactive compounds like linalool and geraniol.
    - **Mechanism:** The compounds in coriander seeds act as natural protectants against pests by repelling insects and preserving the quality of stored grains.
    - **Example:** Crushed coriander seeds can be used in grain storage containers to safeguard crops like rice and lentils from infestations by pests such as the red flour beetle.

Factors to be considered for choosing plant materials and oils as a preservants of food grains

1. **Botanical Characteristics:** The selection of plants for pest control in storage should prioritize traits such as ease of cultivation, cost-effectiveness, non-invasiveness, and potential additional economic uses, optimizing resource utilization.
2. **Effect on Seed Viability:** Consideration should be given to the impact of plant materials on seed germination following storage, ensuring that treated seeds maintain their viability for subsequent planting or consumption.
3. **Toxicological Evaluation:** Rigorous evaluation is necessary to ascertain the safety of handled or consumed materials, adhering to stringent toxicological standards to mitigate potential health risks.
4. **Effect on Food Quality:** Materials chosen for pest control should not compromise the taste, smell, or handling characteristics of stored commodities, ensuring the preservation of quality.
5. **Acceptability:** Tasting trials should be conducted to assess consumer satisfaction, confirming the suitability of treated products for consumption after storage and customary preparation methods.

Registration and toxicological testing

Conducting toxicity studies on plant materials and extracts for unintended organism effects is crucial. Using plants with insecticidal properties may expose humans and pets to toxins. Utilizing whole-plant material is less controversial, as extraction concentrates toxins.

Any extraction process must undergo thorough toxicological testing and registration. Organizations should refrain from endorsing materials lacking formal approval Due to high costs, commercial companies may find using unaltered plant material more viable, especially in developing countries where registration isn't necessary.

Conclusion

Organic preservation of food grains with herbs employs traditional and innovative methods to ensure sustainable storage. Techniques such as aerial storage in tied bundles, underground pits, and earthen bins utilize natural materials to deter pests and regulate moisture levels. Innovations like mud rhombuses and cow dung coating offer eco-friendly solutions for long-term preservation. By harnessing the inherent properties of herbs, including their antimicrobial and insect-repellent qualities, these methods extend shelf life while minimizing environmental impact. Embracing organic approaches for grain preservation with herbs reflects a growing preference for natural, sustainable practices in food storage, promising a greener future for grain preservation.

Future prospects

The future of organic preservation of food grains with herbs is promising, with research focusing on optimizing herbal combinations and application methods for maximum efficacy. Advancements in technology, such as precision agriculture and biotechnology, offer opportunities for sustainable cultivation and extraction processes, making herbal preservation solutions more accessible. Additionally, exploring the role of herbal preservation in reducing post-harvest losses and food waste is crucial for enhancing food security. As consumer demand for natural, eco-friendly products grows, there is a significant market opportunity for organic preservation methods. Overall, this field holds potential for sustainable food systems, environmental conservation, and improved global food security.

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