E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2025; 8(2): 40-46
Received: 13-12-2024
Accepted: 20-01-2025

Namita Shukla
College of Dairy Science and Food Technology, Raipur. Dau Shri Vasudev Chandrakar Kamdhenu Vishwavidyalaya, Durg, Chhattisgarh, India

AK Tripathi
College of Dairy Science and Food Technology, Raipur. Dau Shri Vasudev Chandrakar Kamdhenu Vishwavidyalaya, Durg, Chhattisgarh, India

Kranti Sharma
College of Dairy Science and Food Technology, Raipur. Dau Shri Vasudev Chandrakar Kamdhenu Vishwavidyalaya, Durg, Chhattisgarh, India

Ashutosh Tiwari
College of Dairy Science and Food Technology, Raipur. Dau Shri Vasudev Chandrakar Kamdhenu Vishwavidyalaya, Durg, Chhattisgarh, India

Corresponding Author:
Namita Shukla
College of Dairy Science and Food Technology, Raipur. Dau Shri Vasudev Chandrakar Kamdhenu Vishwavidyalaya, Durg, Chhattisgarh, India

Addressing food security threats: Rodent management in grain storage facilities

Namita Shukla, AK Tripathi, Kranti Sharma and Ashutosh Tiwari

DOI: https://doi.org/10.33545/2618060X.2025.v8.i2a.2572

Abstract
Rodent infestations in grain storage facilities pose significant challenges to food security, agricultural productivity, and public health. Rodents, such as mice and rats, cause extensive damage through consumption, contamination, and physical destruction of stored grains, leading to substantial economic losses. This study explores the various problems associated with rodents in grain storage and proposes solutions that encompass both preventive measures and action plans. Factors influencing rodent infestations include inadequate storage conditions, improper grain handling practices, and proximity of storage facilities to rodent habitats. The challenges posed by rodents are multifaceted and include the introduction of harmful microorganisms, structural damage to storage facilities, and health risks associated with rodent-borne diseases. Traditional pest control methods, such as the use of chemical rodenticides, have limitations, and may lead to the development of resistance in rodent populations. Effective solutions for rodent control involve the implementation of Integrated Pest Management (IPM) strategies that combine various control techniques to minimize pest populations while reducing reliance on chemical interventions. The use of advanced technology in monitoring and control, structural modifications of storage facilities, and community awareness and education programs are essential components of a comprehensive approach to rodent management. Collaboration with agricultural and pest control experts is crucial in developing tailored strategies that address the unique challenges of each grain storage operation. By adopting sustainable and ecologically based management practices, stakeholders can effectively mitigate the impact of rodents on grain storage, thereby ensuring food safety and security.

Keywords: Rodent infestations, grain storage, food security, integrated pest management, contamination

Introduction
Rodent infestations in grain storage facilities pose a significant threat to food security and agricultural sustainability. Rodents, particularly rats and mice, not only consume substantial quantities of stored grains but also compromise food safety through contamination and pathogen transmission, thereby impacting public health. Grain storage facilities are susceptible to infestation by various pests, including rodents, which can have significant consequences on the quality and quantity of stored grains (Bell, 2014) [6]. Rodents, such as mice and rats, are particularly problematic as they can cause extensive damage through consumption, contamination, and physical destruction of stored grains. (Bell, 2014) [6] Their presence can lead to substantial economic losses for grain producers, processors, and consumers. Rodent infestations during grain storage can lead to the introduction of harmful microorganisms, such as fungi, which can produce mycotoxins. These toxins pose serious health risks to humans and livestock that consume contaminated grain. Moreover, rodents can burrow into the grain, creating pathways for moisture and air circulation, further exacerbating the growth of fungi and the deterioration of grain quality. (Abdullah *et al.*, 2019) [2] As global agricultural production increases to meet the rising food demand, effective rodent control in storage facilities is crucial. Neglecting this issue can result in immediate financial losses and long-term implications for food safety and availability. This study examines the various challenges posed by rodents in grain storage and proposes solutions encompassing both preventive measures and intervention strategies. By comprehensively addressing these issues, stakeholders can enhance grain protection against rodents, thereby improving the safety of the food supply.

1. Overview of rodent impact on grain storage
Grain storage is crucial for food security and for mitigating damage from pests, particularly rodents, which are known to cause significant issues in storage facilities. The necessity for effective grain storage is paramount, especially in developing regions, where it is estimated that 20-30% of grains can be lost post-harvest due to pests, including rodents (Quellhorst *et al*., 2018) [19]. This challenge necessitates novel storage methods that can protect grains from pest infestations and spoilage. For instance, hermetic storage technologies have been demonstrated to be cost-effective solutions to pest problems without the use of harmful insecticides (Quellhorst *et al*., 2018) [19]. Furthermore, programs aimed at educating farmers about postharvest management are essential to promote improved storage practices. These efforts not only enhance storage outcomes but also contribute to addressing food insecurity in communities, illustrating the relationship between effective storage methods and sustainable agriculture. Rodents significantly impact grain storage, which is a critical issue, particularly as agricultural intensification accompanies urban expansion, providing these pests with more favourable habitats. Rodents consume grain, resulting in substantial losses, and contaminate food supplies, leading to health risks and exacerbating food shortages. In sub-Saharan Africa, this problem is exacerbated by poor management practices that primarily rely on chemical rodenticides, which are ineffective and potentially harmful to the environment (Meheretu *et al*. 2024) [16]. Moreover, substantial postharvest losses (PHL) in the market chain undermine economic stability; for example, physical losses in crops such as potatoes and bananas demonstrate the urgency of this issue (Abass *et al*., 2017) [1]. More effective solutions are required to mitigate these impacts; therefore, sustainable rodent management is critical for ensuring safe grain storage and food security.

2. Factors Influencing Rodent Infestations
Several factors contribute to the prevalence of rodent infestations in grain storage facilities. Inadequate storage conditions such as high temperature and humidity can create an environment conducive to rodent proliferation (Ziegler *et al*. 2021) [26]. Improper grain handling and storage practices, such as leaving access points for rodents, can increase the risk of infestation.

Grain storage facilities that lack effective rodent control measures, such as proper sealing, regular inspections, and use of deterrents, are more vulnerable to rodent problems. Proper moisture content and temperature control are critical for maintaining the grain quality and deterring rodent activity. In addition, the proximity of grain storage facilities to natural habitats or other sources of rodent populations can contribute to the risk of infestation.

3. Rodent Populations and Feeding Behaviours
Rodents, such as mice and rats, can cause significant damage to stored grains through their feeding and nesting behaviours. Mice and rats are opportunistic feeders that consume a wide variety of grains including wheat, corn, and rice (Ziegler *et al*. 2021) [26]. These rodents consume large quantities of grain, leading to significant losses in both quantity and quality.

Rodents also contaminate grains with urine, feces, and hair, which can introduce harmful microorganisms and pose health risks to both humans and livestock. (Abdullah *et al*., 2019) [2] Furthermore, rodents can burrow into the grain, creating pathways for moisture and air circulation, which can accelerate the growth of fungi and the deterioration of the grain. (Bell, 2014) [6].

4. Challenges Posed by Rodents in Grain Storage
The challenges posed by rodents in grain storage are multifaceted, and can significantly undermine food security and agricultural productivity. Rodents not only consume vast amounts of stored grains but also contaminate food supplies with droppings, urine, and fur, leading to health risks for consumers. Postharvest losses due to rodent infestations may account for a substantial percentage of overall losses, paralleling issues faced with insect pests, where an estimated 20-30% of grain is lost (Quellhorst *et al*., 2018) [19]. The complexities of rodent management are exacerbated by inadequate storage practices often employed by smallholder farmers, who may lack access to modern, pest-resistant storage technologies (Gerpacio *et al*.2025) [10]. Therefore, addressing rodent challenges requires a comprehensive strategy that combines improved storage solutions, pest management education, and community support to mitigate the socioeconomic impacts on these vulnerable agricultural groups.

A. Types of rodents commonly found in grain storage
Grain storage facilities in India face a significant challenge in the form of rodent infestations, which can lead to substantial losses in both quantity and quality of stored grains. The most prevalent rodent species found in these storage facilities are house, brown, and black rats. (Hakeem *et al*., 2017) [11] (Morya & Kumar, 2020) [18].

The house mouse (**Mus musculus**) is a ubiquitous pest that is often found in close proximity to human habitats, including grain storage facilities. These mice thrive in warm and humid environments, and their small size allows them to easily penetrate even the tightest storage structures. They are prolific breeders capable of producing up to 10 liters per year, further exacerbating the issue of infestation.

The brown rat, also known as the Norway rat, is another common rodent found in grain-storage facilities. These rats are larger than house mice and are known for their burrowing habits, which can compromise the structural integrity of storage structures. Furthermore, brown rats are highly adaptable and thrive under a wide range of environmental conditions (Witmer & Shiels, 2017) [25].

Black rats, or ship rats, are significant pests in grain storage facilities. These rats are adept climbers and can easily access storage structures, causing damage through their gnawing behaviour and contaminating stored grains with droppings and urine (Witmer & Shiels, 2017) [25].

All three rodent species are known for their ability to adapt to various environmental conditions, their high reproductive potential, and their propensity to cause extensive damage to stored grains. Effective management strategies to control these pests are crucial for minimizing postharvest losses and ensuring the safety and quality of stored grains.

B. Economic losses due to rodent damage
The economic impact of rodent damage on grain storage is considerable and undermines the efforts of farmers and agricultural systems worldwide. Rodents not only consume a significant portion of stored grains but also contaminate products with droppings and urine, rendering them unfit for consumption and ultimately leading to increased food insecurity. Rodent damage can also lead to indirect costs such as the need for additional cleaning and disinfection efforts, the potential for

spoilage of other stored commodities, and an increased risk of disease transmission.

Research has indicated that effective post-harvest management strategies are crucial for mitigating these losses. However, until recently, such measures have received insufficient attention compared with production research. In regions like Limpopo Province, studies have identified rodents as a primary constraint in post-harvest operations, along with other factors such as transport logistics (Randela *et al*.2025) [21]. Rodents can cause large losses after harvest, with estimates showing that they can damage approximately 20-30% of grain supplies, making it harder for those who already have food scarcity (Quellhorst *et al.*, 2018) [19]. This situation is worse in developing areas where normal pest control methods do not work very well. Traditional methods, such as chemical rodenticides, have unclear success and cause health and environmental concerns (Meheretu *et al.*, 2024) [16]. Thus, there is a clear need for new sustainable management techniques. Methods such as ecologically based rodent management (EBRM) could be good alternatives to reduce economic damage and support a healthier environment. Dealing with rodent problems using focused and eco-friendly approaches is crucial for protecting farming resources and improving food safety.

C. Health risks associated with rodent infestations

There are many health risks from rodent contamination in grain storage that go beyond just physical damage to the crops. Rodents carry germs that can increase the risk of diseases transmitted to humans through contaminated food. In addition, their waste can contaminate grains and help harmful fungi such as Aspergillus flavus grow, leading to serious health problems such as liver issues and cancer, especially in vulnerable groups (Fandohan *et al.,* 2010) [9]. Hantaviruses, which can cause severe and potentially fatal respiratory illnesses, are a prime example of the dangers associated with rodents. (Schmaljohn & Hjelle, 1997) [23] Rats and other rodents are known to be reservoirs for various zoonotic pathogens, and their presence in close proximity to humans can lead to direct or indirect transmission of these harmful agents.

The transmission of hantaviruses occurs primarily through contact with infected rodents, their urine, feces, saliva, or by inhaling virus-contaminated dust from their nests or burrows (Schmaljohn & Hjelle, 1997) [23]. Outbreaks of hantaviral diseases have been linked to changes in rodent population densities, which can fluctuate significantly over time due to seasonal and annual variations. (Schmaljohn & Hjelle, 1997) [23] Leptospirosis, another serious rodent-borne disease, also poses a significant threat, especially in regions with poor sanitation and drainage infrastructure, where rats and other rodents can thrive.

Person-to-person transmission of hantaviruses is rare but has been documented in certain outbreaks, particularly those associated with the Andes virus in Argentina and Chile. In general, the highest risk of exposure is associated with entering or cleaning rodent-infested structures, as this can lead to the aerosolization of virus-laden dust. ("Hantavirus Pulmonary Syndrome - United States: Updated Recommendations for Risk Reduction," 2002) [12] Occupational or recreational activities that bring humans into contact with infected rodents, usually in rural settings, also carry an elevated risk of hantavirus infection. (Schmaljohn & Hjelle, 1997) [23].

The control and prevention of rodent-borne diseases require a multifaceted approach, including effective rodent population management, improved sanitation and hygiene practices, and the provision of education and awareness programs for at-risk communities.

D. Structural damage to storage facilities

The integrity of grain storage facilities is crucial for maintaining the quality of stored products, particularly in the context of rodent infestation. Structural damage, whether from environmental factors or pest activity, can create vulnerabilities that exacerbate rodent problems. Openings and cracks in storage buildings not only facilitate rodent entry but also allow for moisture ingress, which can lead to further degradation of the grain quality. Studies have indicated that thorough cleaning and maintenance of storage structures are effective in managing pest populations, as highlighted by recent reports on organic grain storage challenges (Anon, 2001) [4]. Moreover, the design of storage facilities must account for enhanced durability and pest resistance; implementing improved designs and monitoring techniques can significantly mitigate the risks related to structural damage and infestations (Coulter *et al.*,1997) [8]. Therefore, reinforcing the structural integrity of grain storage facilities is essential to develop effective pest management strategies.

E. Damage to grain quality and quantity

Rodents affect grain storage, not just how much grain is collected, but also its quality, which threatens food security. Rodents eat a large amount of grain, causing direct losses that can be as high as 20-30% of what is harvested because of problems such as rodent infestations and competition from insects (Quellhorst *et al.*, 2018) [19]. Moreover, grains that are not fully eaten may still be contaminated with rodent waste, leading to safety concerns and a decrease in market value. This quality loss can have serious economic effects, as many crops, including potatoes and bananas, lose value because of quality issues, with financial losses often being greater than physical losses in fresh value chains (Abass *et al*., 2017) [1]. Thus, proper rodent control and new storage methods are essential to protect the grain quality and ensure food availability.

F. Environmental implications of rodent populations

India is the second largest producer of rice globally, with an annual production of over 105 million tons. (Kumar & Kumar, 2017) [14] However, the storage and preservation of this critical food source are often compromised by the damaging effects of rodent populations. Rodent populations have significant environmental implications, particularly in agricultural contexts, where grain storage is critical. The increase in rodent numbers, driven by factors such as urbanization and agricultural intensification, indicates a pressing need for effective management strategies. Conventional methods, primarily reliant on synthetic rodenticides, have demonstrated limited success and carry notable environmental and health risks, as highlighted in recent studies ((Meheretu *et al*., 2024)) [16]. These practices not only fail to sustainably reduce rodent populations, but can also lead to unintended consequences, such as harming non-target species and contaminating ecosystems. In addition to the direct loss of grain, rodent infestations can also lead to increased mold growth and aflatoxin contamination, which can compromise the nutritional value and safety of stored food.

The environmental implications of rodent-driven losses are multifaceted. First, the loss of valuable food resources has a direct impact on the food security and livelihoods of farmers and communities. Furthermore, the increased reliance on pesticides and other chemical treatments to control rodent populations can have detrimental effects on the surrounding ecosystem, leading to contamination of soil, water, and non-target species. (Hakeem *et al.*, 2017) [11]. To address these challenges, a comprehensive approach that combines improved storage techniques, the use of non-chemical grain protectants, and the promotion of natural predators of rodents is needed. By adopting these strategies, we can reduce the environmental impact of rodent infestations and ensure sustainable storage and preservation of India's critical grain resources.

G. Common Rodent Species in Grain Storage

The presence of common rodent species in grain storage facilities poses a significant challenge to agricultural productivity and food security. Among the prevalent species, the brown rat and house mouse are the most problematic, often infiltrating grain stores because of their adaptability and rapid reproductive rates. The identification of key rodent species that pose significant threats to agricultural products is essential for managing rodent populations in grain storage facilities. Species such as the brown rat (Rattus norvegicus) and house mouse (*Mus musculus*) are notorious for their adaptability and reproductive capacity, leading to high population densities in the storage areas. Effective control strategies hinge upon a comprehensive understanding of the habitats, behaviors, and ecological roles of these species, as their presence can substantially impact food security and public health. These rodents contribute to substantial post-harvest losses, with estimates suggesting that rodent damage can reach up–30-40% in vulnerable areas, exacerbating the difficulties faced by smallholder farmers, particularly in regions such as Tanzania, where maize is a staple crop (Rosentrater *et al.*, 2015) [22]. Furthermore, their presence not only results in material losses but also raises public health concerns due to the potential spread of the disease. Understanding the behavioural patterns of rodents in storage facilities is critical for the effective management of grain storage contexts. Rodents, particularly Norway rats and house mice, exhibit foraging behaviours that are heavily influenced by the availability of food and shelter. These pests often navigate storage spaces, exploiting structural vulnerabilities to access grains, a behaviour characterized by both nocturnal activity and explorative tendencies in the search for sustenance. To combat these issues, it is essential to develop sustainable and ecologically based management strategies, as highlighted in recent literature that emphasizes understanding rodent behaviour and implementing community-driven interventions (Meheretu *et al.*, 2024) [16].

H. Habitat preferences and nesting behaviours

Understanding habitat preferences and nesting behaviours of rodents is crucial for managing their populations in grain storage facilities. Rodents, particularly species such as house mice and black rats, prefer environments that offer shelter, such as spaces found in grain storage areas. These habitats provide not only protection from predators, but also access to food resources, which significantly influences their nesting behaviour. The house rat, known as Rattus rattus, is the predominant rodent species associated with grain storage in India. These rats have a strong preference for warm, dark, and enclosed spaces, often nesting in the crevices and corners of the storage facilities. They are skilled climbers and can easily access grain stores even in well-sealed structures. In a study conducted in a cold storage facility, researchers found that house rats caused significant damage to a variety of fruits and vegetables including potatoes, cauliflower, sweet oranges, mangoes, grapes, and apples. The rats were also observed to have a preference for damaging packaging materials, such as jute bags and cardboard boxes, over more durable options, such as wooden boxes.

Understanding habitat preferences and nesting behaviours of these rodents is crucial for the development of effective control strategies.

5. Challenges in Managing Rodent Populations

The management of rodent populations in grain storage facilities poses significant challenges, particularly in ensuring food security and minimizing postharvest losses. One of the primary challenges is the ability of rodents to adapt to different environments and develop resistance to control measures. Rodents are known to be highly resilient and can quickly recover from population decline, making it difficult to achieve long-term control. Another challenge is the potential development of chemical resistance in rodents, particularly when relying solely on the use of rodenticides. Repeated exposure to the same chemical can lead to the emergence of resistant populations, thereby reducing the effectiveness of this control method (Witmer & Shiels, 2017) [25]. Furthermore, the use of chemical control methods can pose risks to the health and safety of workers, as well as the quality of the stored grain. Improper handling or accidental contamination of grain can lead to the presence of harmful residues, making the grain unsuitable for human or animal consumption.

A. Limitations of traditional pest control methods

Traditional pest control methods such as the use of chemical rodenticides have several limitations. Chemical rodenticides can be effective in eliminating rodent populations in the short term; however, they may not provide long-term solutions. These methods can also pose risks to the health and safety of workers and the environment and may result in the development of resistance in rodent populations over time. (Bell, 2014) [6]. Another limitation of traditional pest control methods is the potential for contamination of the stored grains. Improper application or accidental spillage of chemical rodenticides can lead to the presence of harmful residues in grain, rendering it unsuitable for human or animal consumption. Thus, the limitations of traditional pest control methods necessitate a shift towards more sustainable and comprehensive approaches that combine education, technology, and community cooperation.

B. Resistance to rodenticides and traps

The increasing resistance of rodent populations to conventional rodenticides and traps poses significant challenges for managing these pests within grain storage facilities. As highlighted in research, traditional methods of rodent control, especially the use of synthetic chemical rodenticides—including first- and second-generation anticoagulants—are becoming less effective due to the development of resistance among rodent species (Meheretu *et al.*2024) [16]. Rodents may also have become accustomed to traditional traps, leading to a decrease in their effectiveness over time. This ineffectiveness not only jeopardizes food security but also raises concerns regarding environmental safety and public health. Furthermore, reactive approaches to rodent management fail to address the root causes of infestations, such as habitat alteration and food availability (Anonymous *et al.*, 2025) [5]. Transitioning towards sustainable alternatives, such as ecologically based rodent management (EBRM), which emphasizes community involvement and an understanding of ecological dynamics, is essential. By adopting such integrative strategies, stakeholders can mitigate resistance development while ensuring long-term effectiveness of rodent control efforts in grain storage environments.

C. Challenges in monitoring rodent populations

Monitoring rodent populations presents significant challenges that complicate effective management strategies for grain storage environments. This difficulty arises from various factors, including variable rodent behaviour, habitat preferences, and population dynamics, which can fluctuate dramatically over time. Traditional monitoring techniques often rely on direct observation and use of rodenticides, which may not adequately capture the complexity of rodent life cycles and interactions with their habitats. Furthermore, reliance on chemical controls without a comprehensive understanding of rodent ecology can yield poor long-term results and potential health risks, underscoring the need for more sustainable management practices. Innovative technologies such as remote sensing and automated monitoring systems can help address this challenge by providing more accurate and real-time data on rodent activity and population levels.

D. Impact of climate change on rodent behaviour

The impact of climate change on rodent behaviour is increasingly relevant to agricultural productivity, particularly in grain storage scenarios. Alterations in temperature and precipitation patterns can drastically affect rodent populations by influencing their food sources and reproductive cycle. Changes in temperature, precipitation, and other environmental factors can influence breeding patterns, feeding habits, and migration patterns of rodents, making it more difficult to predict and effectively control their populations. Consequently, understanding the behavioural adaptations of rodents in response to climate change is crucial for developing effective management strategies to mitigate their impact on grain storage systems.

E. Regulatory and ethical considerations in rodent control

Effective rodent control in grain storage facilities requires a careful balance between regulatory obligations and ethical considerations. Specifically, various regulations govern the use of pesticides and rodenticides, mandating adherence to safety protocols that prevent harm to nontarget species and the environment. Compliance with these regulations not only ensures public safety, but also addresses ethical concerns related to biodiversity and ecosystem health, particularly in agricultural settings where synthetic biology practices (Alphey *et al*.,2019) [3] are considered to sustainably manage pest populations. Additionally, initiatives such as We Care principles emphasize the importance of responsible farming, advocating for practices that prioritize animal welfare, environmental stewardship, and community health (Miller,2022) [17]. These regulatory frameworks and ethical guidelines encourage stakeholders in the grain storage sector to adopt integrated pest management strategies, ensuring that rodent control methods are both effective and socially responsible, thereby safeguarding food security and community trust.

6. Effective Solutions for Rodent Control

Addressing rodent infestations during grain storage requires a nuanced approach that incorporates both immediate and sustainable solutions. Traditional methods, primarily reliant on synthetic rodenticides, are often ineffective and pose significant health risks, necessitating a shift towards more sustainable practices such as ecologically based rodent management (EBRM). This method emphasizes understanding rodent behaviour and habitat use, thereby facilitating community-driven interventions that not only reduce rodent populations, but also maintain long-term effectiveness and environmental safety. To address the challenges of rodent control in grain storage facilities, a multifaceted approach involving integrated pest management strategies is required. By fostering integrated pest management strategies and promoting awareness among stakeholders, we can enhance grain storage practices and effectively mitigate the challenges posed by rodent infestation.

A. Integrated Pest Management (IPM) strategies

Integrated Pest Management (IPM) strategies are increasingly recognized as vital for addressing rodent infestations in grain storage facilities, particularly given the challenges posed by conventional pest control methods. By emphasizing a holistic approach that combines various control techniques, IPM aims to minimize pest populations while reducing reliance on chemical interventions. This multifaceted strategy includes methods such as enhancing store structure cleaning through vacuum and steam treatments to eliminate potential habitats for rodents, as highlighted in recent research (Anon,2001) [4]. Physical control methods, such as the use of rodent-proof construction materials and installation of physical barriers, can effectively prevent rodent access to grain storage facilities.

Additionally, the integration of natural biological controls and improved monitoring techniques can lead to a more effective management of rodent populations. Biological control methods, such as the introduction of natural predators such as snakes or owls, can also be a valuable complement to physical and chemical control measures. (Bell, 2014) [6]. Ongoing monitoring and regular inspections are crucial for early detection and prevention of rodent infestations. (Simmons 1958) [24].

B. Use of advanced technology in monitoring and control

n the realm of grain storage, the application of advanced technology has become indispensable for the effective monitoring and control of pest populations, particularly rodents. Innovative solutions such as digital surveillance systems, which utilize motion detection and thermal imaging, allow for real-time monitoring of storage facilities and enhance the ability to promptly identify rodent activity. Moreover, the implementation of data-driven analytics can help assess various environmental factors, ultimately improving the conditions of stored grains to deter infestation. These technologies not only mitigate harvest losses but also address critical challenges posed by pests, such as the contamination of grains with harmful substances, such as aflatoxin (Lanier *et al*. 2018) [15]. As evidenced by studies in different agricultural settings, a comprehensive approach that combines technological advancements with sustainable practices and sound storage tactics can significantly reduce postharvest losses and ensure food security (Abass *et al.*, 2017) [1]. Thus, the integration of such innovations is vital for modern grain management systems.

C. Structural modifications to grain storage facilities

Addressing the issue of rodent infestation in grain storage facilities requires strategic structural modifications that enhance security and reduce vulnerability. The implementation of features such as reinforced walls, sealed entry points, and elevated storage systems can significantly mitigate rodent access and nesting opportunities. As highlighted in a recent analysis, bulk storage and handling methods not only optimize operational costs, but also create environments that are less conducive to pest habitation (Compton *et al*.,1991) [7].

Furthermore, the evaluation of various small-scale storage technologies, particularly in sub-Saharan Africa, emphasizes the importance of adapting structures to local conditions to effectively combat storage losses caused by rodents. Solutions, such as the use of metal tanks or improved bagging systems, can deter pests while ensuring grain quality (Harding *et al.*,1995) [13]. Ultimately, structural modifications tailored to specific storage needs can serve as both a preventative measure and a means of preserving the integrity of grain supplies against persistent rodent threats.

D. Community awareness and education programs

Community awareness and educational programs play a vital role in addressing the challenges posed by rodents in grain storage, particularly in rural agricultural communities. Effective educational initiatives are crucial for disseminating knowledge regarding proper storage techniques and rodent control methods. These programs not only improve technical skills in postharvest loss minimization but also foster community involvement in tackling issues related to rodent infestations. Furthermore, by identifying barriers, such as poverty and limited infrastructure, education programs can develop tailored strategies that resonate with local realities, ultimately reducing both physical and economic losses stemming from rodent activity (Abass *et al.* 2017) [1]. Through informed community participation, agricultural stakeholders can collectively mitigate the adverse effects of rodents, bolstering food security and economic sustainability.,

E. Collaboration with agricultural and pest control experts

Effective collaboration with agricultural and pest control experts is critical for developing comprehensive strategies to combat rodent infestations within grain storage facilities. These experts provided valuable insights into the ecological factors contributing to pest problems and the implications of storage conditions on grain quality. By working together, stakeholders can implement integrated pest management approaches that encompass both preventative and remedial measures, thereby reducing postharvest losses. By leveraging the expertise of these professionals, grain storage operators can develop and implement comprehensive and tailored pest management strategies that address the unique challenges of their operations.

Conclusion

In conclusion, the implementation of sustainable rodent management strategies is crucial for addressing the persistent challenges posed by rodents in grain storage facilities. Emphasizing an integrated approach that combines preventive measures, ecological considerations, and community engagement can yield substantial benefits. Effective practices, such as enhancing structural integrity to prevent access, implementing regular monitoring programs, and utilizing biological control methods, not only mitigate rodent populations but also reduce reliance on harmful chemicals. Furthermore, fostering cooperation among stakeholders, including farmers, grain handlers, and pest management professionals, ensures a comprehensive strategy that aligns with environmentally responsible practices. By prioritizing sustainability, grain reserves can be protected while safeguarding ecosystems and public health. Ultimately, promoting awareness and education about sustainable practices will enable stakeholders to adopt effective management strategies, contributing to long-term success in controlling rodent populations during grain storage.

References

1. Abass A, Adebayo K, Kikulwe E, Mayanja S, Nabukeera S, *et al*. Postharvest losses along the cooking banana, potato, and cassava fresh value chains in Uganda. [Internet]. 2017. Available from: https://core.ac.uk/download/334410339.pdf
2. Abdullah MSM, Rahiman MHF, Zakaria A, Kamarudin LM, Mohamed L. A Review on Moisture Measurement Technique in Agricultural Silos. IOP Conference Series Materials Science and Engineering. 2019;705:12001. doi: 10.1088/1757-899X/705/1/012001.
3. Alphey L, Bennet E, Campbell K, Delborne A, *et al*. Genetic frontiers for conservation: An assessment of synthetic biology and biodiversity conservation. IUCN; 2019. Available from: https://core.ac.uk/download/237699419.pdf
4. Anon. Integrated grain storage - technology transfer for organic farming. [Internet]. 2001. Available from: https://core.ac.uk/download/10923913.pdf
5. Anonymous, Hinds LA, Singleton GR, Wang Z-W. Rodent Biology and Management; Abstracts of papers presented at the International Conference on Rodent Biology and Management, held at Beijing, China, 5-9 October 1998. [Internet]. 2025. Available from: https://core.ac.uk/download/pdf/6699524.pdf
6. Bell C. Pest control of stored food products: insects and mites. Elsevier eBooks. 2014. p. 494. doi: 10.1533/9780857098634.3.494.
7. Compton JAF, Friendship CAR. Bag or bulk? A decision-making checklist (NRI Bulletin No. 45). Natural Resources Institute. 1991. Available from: https://core.ac.uk/download/19955958.pdf
8. Coulter J, Hindmarsh P. Grain storage in the northern communal areas of Namibia. Natural Resources Institute. 1997. Available from: https://core.ac.uk/download/42389933.pdf
9. Fandohan P, Hell K, Mutegi C. Aflatoxin control and prevention strategies in maize for Sub-Saharan Africa. [Internet]. 2010. Available from: https://core.ac.uk/download/235686259.pdf
10. Gerpacio RV, Pingali PL. Tropical and Subtropical Maize in Asia: Production Systems, Constraints, and Research Priorities. [Internet]. 2025. Available from: https://core.ac.uk/download/pdf/6499382.pdf
11. Hakeem SA, Wani RA, Alie BA, Haq SA, Nissa Sun, Bashir S, *et al*. Management of Maize Weevil (*Sitophilus zeamais*) Using Different Grain Protectants. Int J Curr Microbiol Appl Sci. 2017;6(8):2520. Doi: 10.20546/ijcmas.2017.608.299.
12. Hantavirus Pulmonary Syndrome - United States: Updated Recommendations for Risk Reduction. PsycEXTRA Dataset. 2002. Doi: 10.1037/e548452006-001.
13. Harding S, Tyler P. A guide to appropriate technologies for small-scale storage of grain in Sub-Saharan Africa. Natural Resources Institute. 1995. Available from: https://core.ac.uk/download/42390031.pdf
14. Kumar VKSS, Kumar A. Seasonal Abundance of Rice Leaf Folder and its Natural Enemies in Irrigated Rice Ecosystem. Int J Curr Microbiol Appl Sci. 2017;6(9):1244. Doi: 10.20546/ijcmas.2017.609.150.
15. Lanier W, Parker D, Salifu W. Qualitative discussion about reducing grain postharvest loss with mobile storage in Ghana, West Africa. Julius-Kühn-Archiv. 2018. Available from: https://core.ac.uk/download/235689505.pdf

16. Meheretu Y. From problem to progress: Rodent management in agricultural settings of sub-Saharan Africa and calling for an urban perspective; c2024. Available from: https://core.ac.uk/download/610746690.pdf
17. Miller H. Application of Pork Checkoff We Care Sustainability Principles To Pork Production: Water, Nutrition, and Biosecurity. Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. 2022. Available from: https://core.ac.uk/download/541386849.pdf
18. Morya GP, Kumar R. Abundance of insect pests population in rice field ecosystem under changing climatic conditions of Eastern Uttar Pradesh. J Pharm Phytochem. 2020;9(2):1593. doi: 10.22271/phyto.2020.v9.i2z.14651.
19. Quellhorst HE. Oxygen Consumption by Grain Storage Pests in Relation to Hermetic Storage Systems and an Evaluation of Postharvest Management Practices by Smallholder Farmers in Haiti. [Internet]. 2018. Available from: https://core.ac.uk/download/529680214.pdf
20. RSK, Annadhifa CL, Zuhria FP, Billa FAS, Lestari PD. Pengetahuan dan Sikap Masyarakat terhadap Bahaya Tikus sebagai Agen Global Penular Penyakit Zoonosis. J Inovasi Hasil Pengabdian Masyarakat. 2022;5(2):234. Doi: 10.33474/jipemas.v5i2.13955.
21. Randela R. The incidence of post-harvest problems among small farmers surveyed in three regions of the Limpopo Province. [Internet]. 2025. Available from: https://core.ac.uk/download/pdf/6813618.pdf
22. Rosentrater KA, Suleiman RA. Current Maize Production, Postharvest Losses and the Risk of Mycotoxins Contamination in Tanzania. [Internet]. 2015. Available from: https://core.ac.uk/download/38931868.pdf
23. Schmaljohn CS, Hjelle B. Hantaviruses: A Global Disease Problem. Emerg Infect Dis. 1997;3(2):95. Doi: 10.3201/eid0302.970202.
24. Simmons P. Pest Infestation Research. Bull Entomol Soc Am. 1958;4(1):39. doi: 10.1093/besa/4.1.39.
25. Witmer GW, Shiels AB. Ecology, Impacts, and Management of Invasive Rodents in the United States. CRC Press eBooks. 2017. p. 193. Doi: 10.1201/9781315157078-10.
26. Ziegler V, Paraginski RT, Ferreira CD. Grain storage systems and effects of moisture, temperature and time on grain quality - A review. J Stored Prod Res. 2021;91:101770.