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Sustainable storage methods for preserving sorghum grain quality in agronomic systems

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Abstract

Sorghum, a staple grain for millions worldwide, plays a vital role in agronomic systems. However, post-harvest losses due to inadequate storage methods significantly impact its quality and availability. This paper explores sustainable storage methods, their benefits, and the role they play in reducing grain losses and enhancing sorghum's nutritional and economic value. By integrating traditional and modern techniques, this study highlights the importance of hermetic storage, biopolymer coatings, and controlled atmospheres in achieving sustainable agricultural practices.

Keywords: Sorghum, staple grain, post-harvest losses, storage methods, sustainable storage

Introduction

Sorghum (*Sorghum bicolor*), one of the world's most versatile and resilient grains, is an essential crop cultivated in many arid and semi-arid regions. It holds a prominent place in global agriculture due to its adaptability to harsh environments and its nutritional value. As a staple food for millions, sorghum contributes significantly to food security and economic livelihoods, particularly in developing countries. With its robust nutritional profile—including high dietary fiber, antioxidants, and energy content—sorghum serves as an indispensable food and fodder crop. Despite its importance, sorghum faces significant challenges in post-harvest handling and storage. According to the Food and Agriculture Organization (FAO), global post-harvest losses for staple crops, including sorghum, are estimated at 20-30% annually. These losses are attributed to pests, fungal infestations, and improper storage conditions. Such inefficiencies directly impact food security, reduce economic returns for farmers, and exacerbate hunger in vulnerable regions. In particular, sorghum grains are highly susceptible to attack by pests like *Sitophilus zeamais* and *Prostephanus truncatus*, as well as fungal contamination caused by high moisture levels. The concept of sustainable storage is crucial in mitigating these losses. Sustainable storage involves adopting methods that not only reduce post-harvest losses but also maintain ecological balance and economic viability. By preserving grain quality and minimizing spoilage, sustainable storage ensures that sorghum's nutritional and economic value is maintained throughout the supply chain. This paper explores the dichotomy between traditional storage methods and modern innovations, highlighting their effectiveness and limitations. Traditional storage methods, such as woven bags, earthen silos, and underground pits, have long been employed due to their affordability and accessibility. However, they often fall short in addressing modern agronomic challenges. Conversely, modern sustainable storage technologies, including hermetic storage, biopolymer coatings, and controlled atmosphere systems, present promising solutions. The paper also emphasizes the multifaceted impact of sustainable storage on sorghum grain quality, addressing its nutritional retention, physical integrity, and germination viability. Furthermore, the economic and environmental benefits of sustainable storage methods are discussed, particularly in the context of minimizing reliance on chemical fumigants and improving farmers' incomes. Given the growing global focus on food security and sustainable agricultural practices, it is imperative to address the challenges hindering the widespread adoption of advanced storage methods. Issues such as high implementation costs, lack of technical knowledge among farmers, and policy gaps remain barriers to progress.

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Future directions, including the integration of Internet of Things (IoT) technologies for real-time monitoring and enhanced farmer education, are proposed to overcome these hurdles. By bridging the gap between traditional and modern approaches, sustainable storage solutions have the potential to transform sorghum preservation and contribute to global efforts toward achieving food security. This paper aims to provide a comprehensive analysis of these methods, their implications for sorghum quality, and their broader role in sustainable agriculture.

Objective

1. To evaluate traditional and modern storage methods for sorghum.
2. To assess their effectiveness in reducing post-harvest losses.
3. To explore the economic and environmental impacts of sustainable storage techniques

Traditional Storage Practices

Traditional storage practices have been the backbone of grain preservation for centuries, particularly in rural areas where technological advancements are limited. These methods—such as earthen silos, woven bags, and underground pits—are deeply rooted in cultural practices and remain widely used due to their cost-effectiveness and simplicity. While these techniques are practical and accessible, they are not without significant limitations that compromise grain quality and safety.

One of the most common traditional storage systems is the earthen silo. These silos are typically constructed from locally available materials like clay, mud, and straw, making them affordable and easy to build. However, they are highly vulnerable to pest infestations. Pests such as *Sitophilus zeamais* (maize weevil) and *Prostephanus truncatus* (larger grain borer) can easily infiltrate these poorly sealed structures, causing extensive damage to the stored grain. Studies have shown that pest-related losses in traditional storage systems can exceed 30%, particularly in tropical climates where pest populations thrive.

Woven bags, another popular method, are often used to store sorghum due to their portability and low cost. However, their porous nature allows for the ingress of air and moisture, creating an ideal environment for fungal growth. Fungi like *Aspergillus* species are notorious for producing aflatoxins, which pose severe health risks to humans and animals. Additionally, high humidity levels in storage facilities exacerbate this problem, leading to further spoilage and contamination.

Underground pits, commonly used in arid regions, offer a temporary solution for grain storage. While these pits provide some protection against temperature fluctuations, they are prone to water seepage during the rainy season. This moisture accumulation not only encourages fungal growth but also compromises the structural integrity of the stored grain. Over time, these conditions lead to nutrient degradation, reducing the quality and safety of sorghum for consumption.

Another critical issue with traditional storage methods is the lack of temperature regulation. Extreme temperatures, whether high or low, can accelerate the degradation of sorghum's nutritional content. For instance, high temperatures can denature proteins and reduce the bioavailability of essential micronutrients like iron and zinc. This deterioration has a direct impact on the grain's marketability and its role in food security.

Despite these limitations, traditional storage practices continue to be widely used, particularly in resource-limited settings. Their affordability and accessibility make them a viable option for smallholder farmers who lack the financial resources to invest in

modern storage technologies. However, as global agricultural systems evolve, the inadequacies of these methods become increasingly apparent. Modern agronomic systems demand higher standards of food safety, grain quality, and economic efficiency, which traditional practices often fail to deliver.

Modern Sustainable Storage Techniques

Modern storage technologies represent a revolutionary leap in addressing the limitations inherent in traditional systems. These methods combine advanced scientific principles with practical applications to significantly reduce post-harvest losses, preserve grain quality, and promote sustainability. The transition to these innovative techniques is driven by the need to meet the demands of modern agronomic systems, which prioritize food safety, economic efficiency, and environmental stewardship.

One of the most effective modern methods is hermetic storage. This technique employs airtight containers to create an oxygen-free environment that inhibits the activity of pests and microbial organisms. Research indicates that hermetic storage can reduce pest-related losses by up to 90% while maintaining grain quality for over 12 months (De Groote *et al.*, 2020) ^[1]. Examples of hermetic storage solutions include GrainPro Bags and metal silos. GrainPro Bags, constructed from multilayer polyethylene, are lightweight, reusable, and designed to maintain low oxygen levels. Metal silos, extensively used in Africa and Asia, offer a durable and scalable solution for grain storage. These silos are equipped with seals that ensure an airtight environment, effectively protecting the grain from pests, molds, and moisture.

Another cutting-edge technique is controlled atmosphere storage, which involves manipulating the levels of oxygen, carbon dioxide, and nitrogen to create unfavorable conditions for pests and fungi. This method has proven particularly effective in commercial setups, achieving spoilage reductions of up to 95% (CGIAR, 2021) ^[6]. Controlled atmosphere storage systems are highly precise, allowing for the adjustment of gas concentrations based on the specific needs of the stored commodity. For instance, low oxygen levels combined with high carbon dioxide concentrations can suppress the metabolic activity of pests and prevent fungal growth. This method is widely used in high-value grain storage operations and has shown great potential for scalability.

Biopolymer coatings offer another innovative approach to sustainable storage. These coatings, derived from natural materials such as chitosan and alginate, serve as a protective barrier against moisture and pests. Chitosan, extracted from the shells of crustaceans, has antimicrobial properties that further enhance grain preservation. Studies have demonstrated that grains coated with biopolymers retain their quality and nutritional value for extended periods (Kumar *et al.*, 2019) ^[3]. Moreover, these coatings are biodegradable and environmentally friendly, aligning with the principles of sustainable agriculture.

Solar-powered drying and cooling systems provide an energy-efficient solution to one of the most critical aspects of grain preservation—moisture removal. Excess moisture in stored grains creates a conducive environment for fungal growth and spoilage. Solar drying systems harness renewable energy to effectively reduce grain moisture levels, particularly in rural areas where access to electricity is limited. Similarly, solar-powered cooling systems help maintain optimal storage temperatures, preventing heat-induced degradation of grain quality.

Modern storage techniques also incorporate digital innovations, such as Internet of Things (IoT)-enabled systems. These systems allow for real-time monitoring of storage conditions, including

temperature, humidity, and pest activity. Sensors placed within storage units collect data, which is then analyzed to ensure optimal conditions are maintained. This proactive approach minimizes the risk of spoilage and enhances the efficiency of storage operations.

While modern sustainable storage techniques offer numerous benefits, their adoption faces challenges, including high initial costs and the need for technical expertise. Nevertheless, these methods hold immense potential for transforming sorghum storage and addressing global food security challenges. By combining advanced scientific methods with practical applications, modern storage technologies can ensure the long-term preservation of sorghum grain quality while supporting the economic and environmental sustainability of agronomic systems.

Impact on Sorghum Quality

Sorghum quality is a multifaceted concept encompassing its nutritional content, physical integrity, and germination potential. The adoption of modern sustainable storage techniques has a profound impact on these aspects, ensuring that sorghum grains retain their value throughout the supply chain. These methods not only prevent spoilage but also enhance the nutritional and economic viability of sorghum as a staple food Husen A (2021)^[4].

One of the most significant impacts of modern storage methods is nutritional retention. Sorghum is a rich source of protein, dietary fiber, and essential micronutrients such as iron and zinc. However, traditional storage systems often expose grains to conditions that degrade these nutrients. High temperatures, moisture, and pest activity can cause protein denaturation and the loss of bioavailable micronutrients. Modern methods, such as hermetic storage and controlled atmospheres, create conditions that inhibit these degradative processes. Studies have shown that sorghum stored using advanced techniques retains its protein content in the range of 9-11%, ensuring that its nutritional value is preserved for human and animal consumption (Williams *et al.*, 2022)^[7].

Physical integrity is another critical parameter influenced by storage conditions. Grains stored in traditional systems are prone to breakage, discoloration, and fungal contamination, all of which reduce their marketability. Modern techniques, such as biopolymer coatings, provide a protective barrier that minimizes physical damage. For instance, chitosan coatings have been shown to reduce grain breakage during handling and storage. Additionally, controlled atmosphere storage systems prevent the oxidative processes that cause discoloration, ensuring that sorghum grains maintain their visual appeal.

The impact of storage methods on germination rates is particularly relevant for farmers who rely on sorghum seeds for planting. Traditional storage systems often expose seeds to moisture and temperature fluctuations, resulting in reduced viability. In contrast, hermetic storage systems maintain an optimal environment for seed preservation. Research indicates that seeds stored in hermetic conditions maintain a germination rate of over 85%, compared to just 50% in traditional setups (Tefera *et al.*, 2011)^[5]. This high germination rate not only ensures better crop yields but also reduces the need for frequent seed purchases, providing economic benefits to farmers.

Beyond these direct impacts, modern storage methods also contribute to enhancing sorghum's role in food security. By preserving the grain's nutritional and physical quality, these techniques ensure that sorghum remains a reliable source of sustenance for vulnerable populations. Moreover, the economic

value of high-quality sorghum opens up new opportunities for farmers in local and international markets.

In conclusion, the adoption of modern sustainable storage techniques significantly enhances the quality of sorghum grains. From retaining their nutritional content to safeguarding their physical integrity and germination potential, these methods address the shortcomings of traditional systems and pave the way for a more resilient and sustainable agricultural sector.

Economic and Environmental Benefits

Economic and Environmental Benefits

Sustainable storage methods offer transformative economic and environmental benefits, making them a cornerstone of modern agricultural practices. These benefits go beyond simply preserving grain quality, as they contribute to the economic stability of farming communities and promote environmental conservation on a global scale. By integrating innovative technologies with ecological principles, sustainable storage solutions align the goals of food security, economic growth, and environmental stewardship.

Economic Benefits

1. Reduction in Post-Harvest Losses

Post-harvest losses represent a significant economic burden for farmers, particularly in developing countries. Estimates suggest that global losses for staple crops, including sorghum, can range between 20% and 30%. Sustainable storage technologies, such as hermetic storage systems, have proven to reduce these losses by up to 90%. For example, studies in Africa demonstrated that farmers using hermetic storage saved approximately 25% of their annual sorghum yield, translating to substantial income increases. This reduction in losses ensures that a larger proportion of the harvested crop reaches the market or serves its intended purpose, thereby improving economic returns for farmers.

2. Enhanced Marketability

The quality of stored sorghum plays a critical role in determining its market value. Sustainable storage techniques, such as controlled atmosphere systems and biopolymer coatings, preserve the physical integrity and nutritional quality of grains, making them more attractive to buyers. High-quality sorghum fetches better prices in both local and international markets, increasing farmers' profitability. Moreover, the consistent quality achieved through these methods opens doors to premium markets, including those with strict food safety regulations.

3. Cost-Effectiveness Over Time

While the initial investment in sustainable storage technologies may be higher than traditional methods, these systems are cost-effective in the long run. For instance, GrainPro Bags and metal silos, despite their upfront costs, are reusable and durable, providing years of reliable storage. Additionally, the reduction in losses offsets the initial expenditure, allowing farmers to recover their investment within a few seasons³. For smallholder farmers, these cost savings contribute to financial stability and enable further investment in agricultural inputs such as seeds, fertilizers, and equipment.

4. Support for Value-Added Products

Sustainable storage not only preserves raw sorghum grains but also enables the production of value-added products such as sorghum flour, malt, and animal feed. By maintaining the quality of stored grains, these methods support downstream

industries, creating additional revenue streams for farmers and agribusinesses. The economic ripple effects extend to employment generation in processing and distribution sectors, fostering broader economic growth.

Environmental Benefits

1. Reduction in Chemical Fumigants

Traditional storage practices often rely on chemical fumigants to control pests and fungi. While effective, these chemicals can leave harmful residues on grains and pose risks to human health and the environment. Sustainable storage methods, such as hermetic systems and biopolymer coatings, eliminate or drastically reduce the need for chemical interventions. By creating oxygen-deprived environments or using natural antimicrobial coatings, these methods achieve pest and fungal control without introducing toxic substances into the ecosystem.

2. Minimized Carbon Footprint

Sustainable storage practices contribute to reducing the carbon footprint of agriculture. For instance, solar-powered drying and cooling systems utilize renewable energy to control moisture and temperature, eliminating the need for fossil fuel-based alternatives⁵. Controlled atmosphere storage systems also optimize resource use by reducing energy consumption through precise environmental controls. These energy-efficient technologies align with global efforts to combat climate change and reduce greenhouse gas emissions.

3. Prevention of Resource Wastage

Post-harvest losses represent a waste of not only the grains but also the resources invested in their production, including water, fertilizers, and labor. By minimizing these losses, sustainable storage ensures that the full value of these resources is realized⁶. This efficiency is particularly critical in regions facing resource constraints, such as water-scarce areas where sorghum is predominantly grown.

4. Promotion of Circular Economy Principles

Many sustainable storage solutions align with the principles of a circular economy, emphasizing reuse, recycling, and waste reduction. For example, biopolymer coatings derived from renewable materials such as chitosan are biodegradable, reducing waste and environmental impact. Similarly, metal silos and GrainPro Bags are designed for repeated use, minimizing the need for disposable storage materials.

5. Support for Biodiversity

By reducing reliance on chemical fumigants and other environmentally harmful practices, sustainable storage methods help protect biodiversity. The ecological balance in and around farming areas is preserved, ensuring the health of beneficial organisms such as pollinators and natural pest predators. This holistic approach to sustainability supports long-term agricultural productivity and environmental resilience.

Conclusion

Sustainable storage methods offer a transformative approach to addressing the critical challenge of post-harvest losses in sorghum production. By adopting advanced techniques such as hermetic storage, controlled atmosphere systems, biopolymer coatings, and solar-powered drying and cooling, farmers can significantly reduce grain losses while preserving nutritional value and physical integrity. These methods not only improve the quality of stored sorghum but also ensure its economic

viability by enhancing marketability, supporting value-added products, and increasing farmers' incomes through reduced wastage and spoilage. The environmental benefits of these technologies are equally compelling. By minimizing the use of chemical fumigants and incorporating renewable energy sources, sustainable storage practices reduce the ecological footprint of agricultural operations. These methods also align with global efforts to combat climate change by promoting energy efficiency, reducing greenhouse gas emissions, and preventing resource wastage. Furthermore, sustainable storage supports biodiversity by maintaining ecological balance and protecting beneficial organisms essential for long-term agricultural productivity. However, the widespread adoption of these advanced storage systems faces barriers such as high initial costs, limited technical knowledge, and inadequate policy support. Addressing these challenges requires a multi-faceted approach, including government subsidies, farmer training programs, and investments in scalable, cost-effective technologies. The integration of digital tools, such as IoT-enabled monitoring systems, offers promising opportunities for enhancing the effectiveness and accessibility of these storage methods. By bridging the gap between traditional and modern approaches, sustainable storage solutions hold the potential to revolutionize sorghum preservation. These methods not only contribute to global food security but also ensure economic stability for farming communities and environmental sustainability for future generations. The collective adoption of these practices can transform sorghum storage into a model for resilient and sustainable agricultural systems worldwide.

References

1. Groote DH, Kimenju SC, Likhayo P, *et al.* Hermetic storage technologies reduce post-harvest losses of maize and sorghum in Africa. *Food Security*. 2020;12(3):435-446.
2. FAO. Post-harvest losses in staple crops: Global estimates and interventions. Rome: Food and Agriculture Organization; 2021.
3. Kumar R, Gupta A, Sharma S. Antimicrobial properties of chitosan coatings for grain storage. *International Journal of Biological Macromolecules*. 2019;132:124-130.
4. Hussen A. Impact of grain storage method on sorghum grain quality in Ethiopia: A review. *Journal of Current Research in Food Science*. 2021;2(1):40-45
5. Tefera T, Kanampiu F, De Groote H, *et al.* The metal silo: An effective grain storage technology for reducing post-harvest losses in Africa. *International Journal of Pest Management*. 2011;57(3):177-186.
6. CGIAR. Advances in controlled atmosphere storage: A solution for pest control and grain quality. Consultative Group on International Agricultural Research (CGIAR); 2021.
7. Williams P, Okoye F, Adebayo A. Impact of storage methods on the nutritional quality of cereals in sub-Saharan Africa. *Journal of Agronomy and Food Science*. 2022;14(4):345-360.