REVIEW ARTICLE

Effective Storage Structures for Preservation of Stored Grains in Nigeria: A Review

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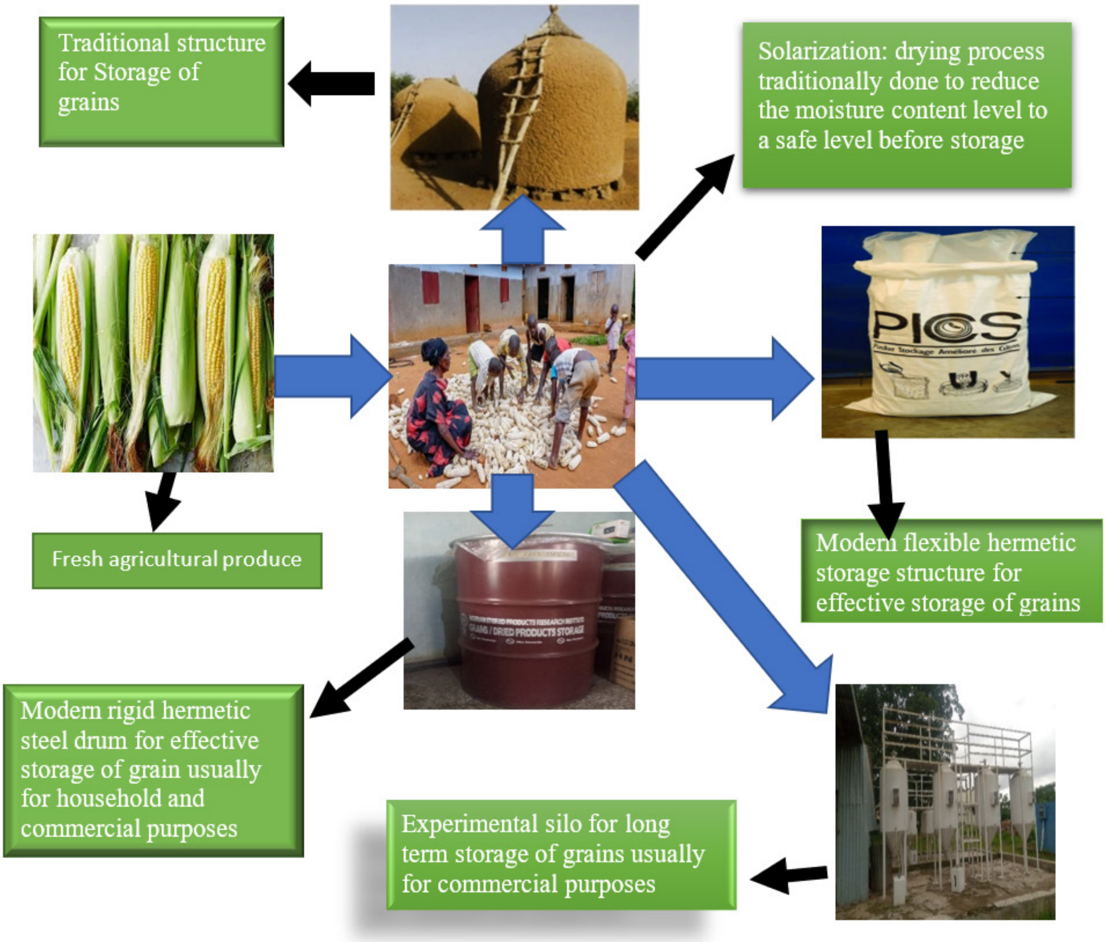

Highlights

- Insufficient storage facilities expose grains to degradation, affecting their quality.
- Traditional storage practices lack durability and moisture protection.
- Hermetic storage solutions play a vital role in maintaining product quality in Nigeria.
- The hermetic system in Nigeria has been shown to reduce post-harvest losses and improve farmers' access to food.

Ceylon Journal of Science 53 (1) 2024: 139-147
DOI: http://doi.org/10.4038/cjs.v53i1.8194

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Received: 08.08.2023;   Accepted: 16.02.2024

Abstract: The preservation of agricultural produce is crucial to ensure food security reducing postharvest losses. Most farm produce begin to deteriorate as soon as they are harvested. Agents of spoilage include environmental conditions, rodents, microorganisms, insect infestations, and poor storage facilities. The traditional storage systems in Nigeria play a crucial role in preserving grains. These structures are designed to protect grains from environmental factors such as humidity and temperature fluctuations, and pests. Commonly used structures include granaries, earthen pots, mud silos, crabs, storage baskets, underground pits, and open-air storage structures. These are used primarily for storing grains such as cowpea, maize, sorghum, millet, and rice. These storage facilities are built using locally available materials and techniques that have been passed down through generations, reflecting the rich cultural heritage of the Nigerian people. The traditional methods of grain storage are effective in reducing post-harvest losses ensuring food security in rural communities. However, the changing landscape of agriculture and the growing demands of modern society have necessitated modern storage structures, thereby maintaining the authenticity and sustainability of the grain. This review aims to provide an overview of various storage structures and their effectiveness in preserving agriculturally stored grains. The review focuses on key factors such as temperature control, humidity control, ventilation, pest control, and structural integrity. The findings of this review can help policymakers, researchers, and farmers to make strategic decisions regarding the selection and design of storage structures for storable crops.

Keyword: Storage Structure, Stored grains, Structural Integrity, Nigeria

INTRODUCTION

Grain is a vital commodity in Nigeria, serving as both animal feed and staple food for human consumption (Ayoade & Adegbite, 2014). The availability and affordability of these agricultural produce, such as maize, wheat, rice, millet, sorghum, soybean, and cowpea, are crucial for sustaining people's livelihoods in Nigeria (Oluwole & Adebayo, 2017). This is particularly important because, a significant portion of the population cannot afford the cost of imported food commodities (Olarinoye et al., 2012). Therefore, it is essential to preserve the surplus grain after meeting the immediate needs of farmers and their families (Oyekale & Adepoju, 2017). Traditionally, farmers in Nigeria have relied on locally made storage structures for storage of grains (Oyeyinka & Adeyeye, 2016). However, Traditional storage structures play a vital role in preserving agricultural produce (Yusuf et al., 2020). While traditional storage methods have been used for centuries, modern storage structures offer numerous advantages in terms of efficiency, improved quality control, and reduced post-harvest losses (Yusuf et al., 2020). However, both approaches have their own sets of benefits and setbacks (Aghalarov et al., 2013). Traditional storage structures in Nigeria include granaries, barns, and silos made from locally-sourced materials such as mud, thatch, and bamboo. These structures have been used by rural communities for generations and have proven to be relatively effective in protecting crops from pests, humidity, and spoilage (Mohammed, 2013). Additionally, traditional storage structures are generally low-cost and easily accessible to farmers in remote areas (Ahmed, 2013). They also provide an opportunity to preserve cultural heritage and local knowledge (Yusuf et al., 2020). However, traditional storage structures do have some limitations (Singh et al., 2017). They are often labor-intensive to construct and maintain, and their capacity is relatively low compared to modern alternatives (Singh et al., 2017). Traditional structures may lack proper insulation, leading to increased vulnerability to pests and moisture (Mohammed, 2013). This can result in significant post-harvest losses. Otitodun et al., (2021) reported that poor storage structures and practices contribute to the loss of macro and micro-nutrients in grains, leading to "hidden hunger" or subclinical nutrient deficiencies. Micronutrient deficiencies can have severe health consequences and reduce the quality of life (FAO, 2014). Each year, a significant proportion of food produced for human consumption is lost or wasted (FAO, 2011). Annual food losses have been estimated at 1.3 billion tonnes, with sub-Saharan Africa experiencing losses exceeding 30% of total crop production (United Nations, 2017). In Nigeria, 90% of food loss occurs within the value chains, directly impacting production, income, food availability, prices, and nutritional content (Rockefeller &Ahmed, 2013). On the other hand, modern storage structures, such as warehouses, silos, hermetic steel drums, hermetic rubbers, hermetic bags and refrigerated storage facilities, have gained popularity in recent years (Ayoade & Adegbite, 2014). These structures are typically made

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of durable materials like concrete, steel, or plastic, and are designed to provide optimal conditions for preserving agricultural produce (Singh et al., 2017). Modern storage structures offer benefits such as increased capacity, better pest control, improved ventilation, and temperature control (Akinbode et al., 2019). They also enable efficient handling and faster transportation of produce, reducing the risk of spoilage during transportation (Singh et al., 2017). Though modern storage structures offer significant advantages, they also come with challenges (Adepoju & Olakojo, 2018). High construction and maintenance costs can hinder small-scale farmers from adopting them (Adepoju & Olakojo, 2018). Additionally, access to modern storage facilities is often limited to urban or peri-urban areas, which may exclude rural farmers with limited transportation resources (Samuel et al., 2019). However, to address these challenges, it is imperative to embrace appropriate storage facilities, practices and maintenance culture to preserve and protect food commodities with minimum losses (Ayoade & Adegbite, 2014).

PRE-FOOD GRAIN TREATMENT

Solarization

Grains are sundried as seen in Figure 1 to keep the moisture content low and to decrease the activities of insects (Adeshina et al., 2019). Farmers have long used this method before storing their grains and pulses in areas where the temperature outside reaches 20 °C or more (Adeshina et al., 2019). Depending on the product, various solarization times are employed, and dried grains are eaten to determine whether they have dried completely (Stathers et al., 2020). It typically relates to grain that is stored for food rather than seed because doing so could lower the viability of the seed (Tefera et al., 2018). Farmers spread the food grains on bare ground or on polythene or tarpaulin, bamboo mats usually by the roadsides, or rooftops to reduce moisture content and destroy the majority of infesting agents of the stored grains (Ayoade & Adegbite, 2014). If the grain is kept in an insect-proof container after drying, it won't become infested (Ofor, 2011). Kiruba et al., (2008) reported that eggs and larva of *Cryptolestes maculatus* and the first instar larva of *C. subinnatatus* were found effectively destroyed by solarization method. However, solarization denatures seeds, causing mold development and aflatoxin-producing fungal growth, increasing health risks in humans (Said, 2020).

TRADITIONAL STORAGE STRUCTURES

In the past, food grains were stored to preserve excess produce and provide enough for survival and for next planting season (Jian & Jayas, 2021). But the main adversaries of grains that are stored are insect pests (Kimatu et al., 2012, Adeshina et al., 2019). According to Ottitodun et al., (2019), temperature, relative humidity, and moisture are the primary factors affecting the ecology of the stored grains. These factors encourage the growth of microorganisms, insects, and mold, reducing the nutritional value and qualities of the stored grain (Nithya et al., 2011). Insect infestation causes severe damage in the form of cracks and holes in grains, which can cause half of the grain loss during storage periods (Fornal et al., 2007). Grain that has been heavily infested has a lower nutritional value (Oke & Akintunde, 2013) and could include harmful substances that are bad for the health of consumers (Modgil, 2003). Food tainted with toxins can have a serious negative effect on human health when consumed (Bryden, 2012). According to Ahmad (2002), the lack of suitable storage structures also makes farmers sell out their grains directly as harvested to avoid losses (Kimenju et al., 2009). Farmers have used a variety of grain storage techniques, such as gourds, earthen bins, rooms, straw-covered piles, metal bins, mud silos, underground pits, and bags. However, these techniques are short of absolute protection of the grains from insect pests, and they also frequently have structural flaws in the walls, foundation, and roof of the buildings including holes (Alonge, 2005).

INDOOR STORAGE STRUCTURES

Gourds

Storage gourds also known as 'calabashes' in Nigeria are large wooden bowls or containers used to store water, grains and food items as seen in Figure 1 (Makalle, 2012). They come in several sizes with most ranging from small handheld objects up to very large ones that people use for sitting (Adeshina et al., 2019). Storage gourds serve several functions within the Nigerian society such as providing drinking water, storing of durables, perishable goods and preserving traditional cultural values (Daniyan et al., 2018). However despite their usefulness there have been some setbacks associated with storage gourds usage in Nigeria due to a number of reasons including: lack of knowledge about how they can be made effectively (Chukwuka et al., 2017); vulnerability against pests like weevils, termites etc.; socio-economic effects such as poverty that limit access to proper materials necessary for building them (Mgbeahuruike & Ukpongzua, 2020) and changes in climate patterns that make harvesting fruit difficult or impossible (Dougan, 2018). Poor accessibility which is caused by inadequate transportation networks making it difficult to travel long distances into rural villages where these products can be found at affordable prices (Daniyan et al., 2018) and difficulty in reaching potential customers who would be interested purchasing them (Audu, 2016).

Earthen Pot

Earthen pots are made from clay soil as seen in Figure 1 and they differ in shape and size depending on the locality; it has a broader top with a narrow bottom with a constructed mouth for easy pouring of grains (Bodholt & Diop, 1987). The pot is placed on a platform to avoid contact with the ground (Saidu & Abba, 2017). The grains to be poured into the earthen pot are dried to a safe moisture content of 12% or less and the pot is filled up with grains to the brim and covered with an earthen plate that fits into the opening and sealed with mud. It's a normal practice among rural farmers that after sealing the mouth of the earthen pot with mud, leaves of plants like *Azadirachta indica* are placed on top to repel insect pests (Blaabjerg et al., 2015). The grain stored in this structure is grain seeds for planting and farmers use this structure because of low cost and easy construction from locally available materials followed by temperature variations that keep the grain seeds cool (Singh et al., 2017). Earthen pots have drawbacks, including increased moisture content in grain seeds during wet seasons, leading to mold formation, pungent smell, and discoloration (Chattha *et al.,* 2013).

Traditional Storage Basket

A traditional basket used for storage as seen in Figure 2 is often woven from natural materials such as straw, grass, or bamboo (Ma & Yao, 2012). These types of baskets are popular in many cultures around the world and have been utilized for thousands of years (Ma & Yao, 2012). However, traditional baskets for storing grains also have some limitations. These limitations include:

1. Limited capacity: because of their size and shape, traditional baskets may not be able to hold large quantities of grains, which can limit their usefulness in some situations.

2. Vulnerability to pests: traditional baskets may not be able to protect stored grains from insects and rodents, which can damage or destroy the grains.

3. Vulnerability to moisture: traditional baskets may not be able to protect stored grains from moisture, which can cause molds and mildews to grow and spoil the grains.

4. Fragility: traditional baskets may be delicate and easily damaged, which can lead to them breaking apart and losing their effectiveness as storage containers.

5. Difficulty in cleaning: traditional baskets may be difficult to clean, which can lead to them becoming dirty and unhygienic over time (Adeshina et al., 2019).

OUTDOOR STORAGE STRUCTURES

Mud Rhombus Storage

Mud rhombus is mostly used for grain storage in lower rainfall regions as seen in Figure 3. this structure stores grain for at least 2- 5 years (Adeshina et al., 2019). As the name implies, the structure is made from a mixture of mud or clay with cylindrical, spherical, or circular-shaped constructed on stones that serve as base support (Kumar & Kalita, 2017). An aluminum sheet or straw mat is used to cover the top to serve as a poor conductor of heat to shield the structure from harsh weather conditions, and rainy and dry seasons. This structure can be used to store cereals and pulses i.e millet, sorghum acha and soybeans (Kumar & Kalita, 2017). The loading of the grain into the structure will require at least four men to manually load the grains into the structure. Depending on the size and height of the rhombus, about 20 persons stay on the ground, bagged the grain, and passes it to the second person who is on top of the bin or a ladder. The third person is inside the structure or on another ladder inside the rhombus collects the heads of the grain and the fourth person arranges it in the rhombus (Kumar & Kalita, 2017). The offloading of the stored grains is done in a way that, part of the bin may be broken to create an opening for easy offloading, the created opening is later sealed after the complete evacuation of the stored grains (Mahai et al., 2015; Kumar & Kalita, 2017). The main setbacks in the use of this storage method are that the structure is not airtight, and moisture contents are increased as a result of varying temperatures and relative humidity. Furthermore, damage often results from rodent pest or insect infestation, structural failure, and termite infestation (Adejumo & Raji, 2007).

Figure 1: Traditional outdoor and indoor storage practices and structures: **A**-Solarization, **B:** Gourd, **C**: Earthen pot. Sources: Mitchell et al., 2012; Nukenine, 2010 and Nukenine, 2010.

Figure 2: Traditional storage baskets (Source: Viet Delta Corporation, 2003)

Traditional Silo (Mud Silo)

A traditional silo is a structure that is spherical and normally built on three or four stones that serve as a support at the base as seen in Figure 3. Unlike the mud rhombus, the traditional mud silo is used for a short duration of food grains storage. It is constructed in a way that the thatch is placed on top of it to prevent direct sunlight and protection against rain, the thatch is usually in an inverted 'V' shape or a cone hangs upside down, also the mud silo exterior could be plastered with cow dung or slightly with cement (David, 1998). The carrying capacity of the structure is between 1 and 4 tons (Nukenine, 2010). It is normally constructed from termite mound soil or clay soil (Arthur et al., 2022). The modern silo structure was adopted from a mud silo and then improved upon by using various materials for its construction (Igbeka, 1983). This storage structure can be used to store maize, sorghum and paddy (Solomon et al., 2019). Since the silo is made of mud, it works better in the dry season (Alonge & Opeloyeru, 2007). This structure is majorly for households and for temporal storage of seeds for planting in subsequent seasons (Solomon et al., 2019). The setbacks in mud storage structures are that, when the blasting effects of wind against the walls of the mud occurs over some time, it causes tear and wear down of the walls thereby softening the mud structure and causing cracks giving access to rodent and other spoilage pests to the stored grain (Arthur et al., 2022).

Underground Pit

The underground pit storage method as seen in Figure 3 is usually done by farmers in agroecological regions where there is low water (Worku et al., 2019). This method can be used to store cowpea, millet, and sorghum ranging from 1000 kg to 200 tons (Adesina et al., 2019). The depth of the pit is usually between 1-3 m and 1–3-m diameter in round or squared shape. The walls and the bottom are insulated with a straw mat or corn husk (Gilman & Boxall, 1974). The bags are then filled with threshed grains and loaded into the pit; thereafter, wooden planks are placed on it to serve as cover with polyethylene or iron sheet (Fairbairn & Omura, 2005). Grains stored in an underground pit are protected against insect infestation because of the reduced oxygen level in the pit and the storage duration is between 1-5 years without opening (Fairbairn & Omura, 2005). However, the repeated opening of underground pits can cause deterioration in the eating and germination qualities of the stored grain (Fairbairn & Omura, 2005). Studies have shown that underground pit storage is not the most suitable option for the long-term storage of grains; and it is not preferred in the cereal industry due to its disadvantages compared to other storage methods. Bulk storage in silos is considered the most preferable technique for long-term storage. Silos, particularly steel and galvanized silos, provide better protection against moisture and pests (Pekmez, 2016).

Open-Air Storage

The major reason grains are stored is to ensure their year-round availability for use as food and as seed for upcoming planting seasons. According to Nisak et al., (2019), local maize varieties have historically been preserved in open-to-air constructions with multiple layers of husk tightly enclosing the cob to offer some protection against common insects as seen in Figure 3. In an outdoor setting, grains can be kept either husked or unhusked Adeshina et al., 2019). The dry season is when this storage method is most frequently used. The problems with this storage strategy, however, include theft, pests like rodents, and the potential for food shortages if there is a fire outbreak in the vicinity (Adeshina et al., 2019).

Crib Storage Structure

A corn crib serves as a storage space and for drying, serving two purposes simultaneously as seen Figure 3. It is used for storage after drying (Demito et al., 2019). Its features include ventilation slats (often horizontal wooden ones) and/or wire netting (metal ones), doors in the ends for accessibility, and rodent-resistance measures (elevating it off the ground, tight flooring) (IITA, 2009). Corn cribs can have gabled or shed roofs, but shed roofs are overwhelmingly more prevalent. The original corn cribs were made of logs, but very few of these still exist. However, the majority of cribs still in use are made of frames. To prevent settling and shed baby weight, "keystone"-shaped cribs with flared tops were created. Corn cribs could be used as a standalone structure or integrated into a barn assembly as an essential component or (perhaps more frequently) as an addition to the shed roof. Early in the 20th century, manufactured corn cribs were made; but, due to World War II's lack of metal, they were never again built (Demito et al., 2019). After World War II, they rose to popularity once more. Because of rising costs for wood and labor as well as the fact that metal cribs were durable and low maintenance, metal cribs became popular. After the mid-1950s, corn cribs were less popular because of changes in harvest technology, including the field-based shelling of corn and the removal of the need for prolonged drying in the crib by artificial dryers. But because of the unrestricted movement of air over the stored product owing to natural ventilation, the crib is shaped in such a way that the drying process continues throughout storage. The crib's original purpose was to store un-threshed maize cobs, but today it is used to store practically all other crops as well (Eesiah et al., 2022). Although this kind of storage facility is simple and inexpensive to construct, it gives very little protection against insect pests, and losses from insects and rodents in storage can frequently reach 40%. Husked maize types offer 3-6 months of reasonable insect protection (Mijinyawa, 2002).

MODERN FOOD GRAIN STORAGE STRUCTURES AND TECHNOLOGIES

Modern food grain storage structures and technologies play a crucial role in ensuring food security and reducing post-harvest losses (Okonkwo et al.,2017). These advancements have significantly improved the quality and shelf life of stored grains, thereby contributing to the overall food supply chain (Perkin et al.,2016; Otitodun et al., 2021). One of the key modern storage structures is the silo (Kongkaew & Kerdsuwan, 2017). Silos are tall, cylindrical structures made of steel or concrete (rigid hermetic) that provide a controlled environment for grain storage. They

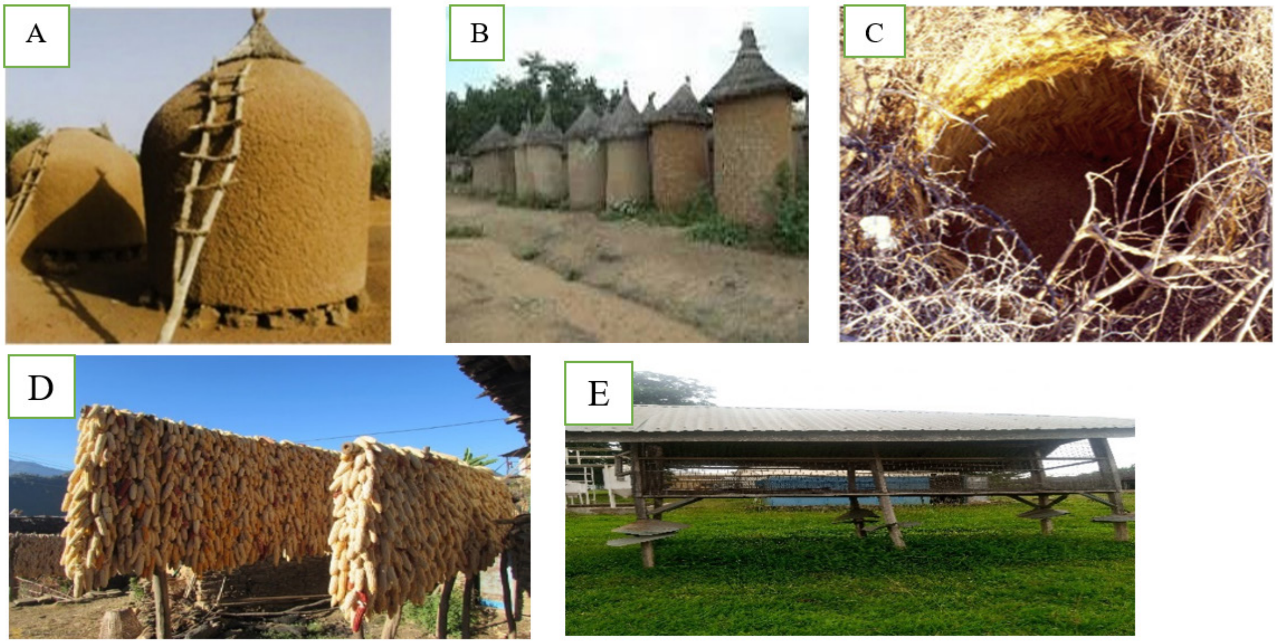

Figure 3: Outdoor storage structures: **A**: Mud Rhombus Storage, **B:** Mud silo, **C:** Underground pit storage, **D**: Open-air storage and **E**: Wooden maize crib*,* Source: Adeshina et al. (2019)

are designed to protect grains from moisture, pests, and other environmental factors that can lead to spoilage (Stathers et al., 2020). Silos are equipped with ventilation systems, temperature and humidity control mechanisms, and pest management systems to maintain optimal storage conditions. Another important technology in modern food grain storage is airtight storage systems (flexible hermetic). Airtight storage involves sealing the bags to prevent the entry of oxygen and moisture (Blaabjerg et al., 2015). This technology helps in preserving the quality of grains by inhibiting the growth of microorganisms and reducing the risk of insect infestation (Walker et al., 2018; Atta et al., 2019). Airtight storage systems are particularly useful in regions with high humidity or where traditional storage methods are inadequate (Watkins & Ekman, 2005). Furthermore, advancements in monitoring and control systems have revolutionized grain storage management. These systems utilize sensors and automation technology to continuously monitor temperature, humidity, and other environmental parameters inside the storage structures. Real-time data from these sensors can be analyzed to detect any deviations from the desired storage conditions and take corrective actions promptly (Mosher, 2019). This not only helps in preventing spoilage but also enables efficient management of grain inventory (Pimentel, 2019). In addition to storage structures and technologies, proper handling and processing techniques are also essential for maintaining grain quality. For instance, pre-cleaning and drying of grains before storage can remove impurities and reduce moisture content, thereby preventing mold growth and insect infestation. More so, the use of fumigants and insecticides can further enhance the effectiveness of storage systems by controlling pests and insects. Overall, modern food grain storage structures and technologies have significantly improved the efficiency and effectiveness of grain storage (Omobowale et al., 2015). These advancements have not only reduced post-harvest losses but also ensured the availability of high-quality grains for consumption. However, it is important to note that the adoption of these technologies may vary depending on the region, infrastructure, and economic factors. Therefore, further research and development efforts are needed to make these technologies more accessible and affordable for small-scale farmers, especially in developing countries.

Flexible Hermetic Storage System

Hermetic storage (HS) technology as seen in Figure 4 has emerged as a significant alternative to other methods of storage that protect commodities from insects and molds (Guillet, 2016). In Sub-Saharan African countries, hermetic bags have been shown to effectively reduce insect-related losses to a minimum of 2% after 100 days of storage, compared to traditional storage methods (Dijkink et al., 2022). This reduction in losses translates to increased income for farmers and improved food and nutrition security (Alemayehu et al., 2023; Dijkink et al., 2022). Flexible hermetic storage facilities are air-tight structures that do not require synthetic chemical application (Lane & Woloshuk, 2017). This technology works on the principle of exclusion of oxygen gas from the storage environment (Yusufe et al., 2017); for example, the use of polythene lined jute bags as tested by the Nigerian Stored Products Research Institute (NSPRI) offers several advantages over other traditional storage methods. Firstly, it is a cost-effective solution as it is relatively inexpensive and readily available. Additionally, the polythene lining provides an extra layer of protection against pests, reducing the need for chemical pesticides. This is particularly important for farmers who aim to minimize the use of chemicals in their agricultural practices. (Okonkwo et al., 2017). The bag is filled to the brim with grains and properly tied or sealed to ensure air tightness. Other flexible hermetic storage structures such as PICS. PICS bags, which stand for Purdue Improved Crop Storage bags, were developed by researchers at Purdue University in the United States (Williams et al., 2017) and ZeroFly® Hermetic bags, on the other hand, are a product developed by Vestergaard Frandsen SA, a Swiss company specializing in disease and vector control solutions. These bags are made of a multi-layered plastic material that provides a hermetic seal and they are treated with an insecticide that kills and repels insects, further enhancing their effectiveness in controlling pest infestation and they have also been successfully used in various countries to protect stored crops from insect damage and reduce post-harvest losses. Both PICS bags and ZeroFly® Hermetic bags offer several advantages over traditional storage methods. Firstly, they provide a hermetic environment that effectively controls insect infestation, reducing the need for chemical pesticides (Kouskolekas 2021). This is particularly important in regions where access to pesticides is limited or where the use of pesticides is undesirable due to environmental or health concerns. Secondly, these bags are easy to use and require minimal training, making them suitable for small-scale farmers who may not have access to sophisticated storage facilities. Finally, these bags are cost-effective and can be reused for multiple seasons, providing a sustainable and affordable solution for crop storage (Baributsa et al., 2010).

Rigid Hermetic Storage System

A rigid hermetic storage system as seen in Figure 5 refers to a storage system that is both rigid and hermetically sealed. Rigidity refers to the structural integrity and stability of the system, while hermetic refers to the ability to create an airtight seal to prevent the exchange of gases or moisture between the storage environment and the outside atmosphere (Guillet, 2016). examples of rigid Hermetics are Inert Atmosphere Silo (IAS), NSPRI Hermetic Steal Drum (NHSD), and plastic jerricans for storage of grains. The use of a rigid hermetic storage system is important in various industries and applications where the preservation and protection of the stored grains are critical. For example, in the food industry, a rigid hermetic storage system can be used to store perishable and durable goods such as fruits, vegetables, and cereal grains respectively, ensuring their shelf-life and preventing spoilage (Varnava et al., 2003). In the pharmaceutical industry, a rigid hermetic storage system can be used to store medications and vaccines, protecting them from degradation and contamination. One of the key advantages of a rigid hermetic storage system is its ability to maintain a controlled environment. By creating an airtight seal, the system can prevent the entry of oxygen, moisture, and other contaminants that can degrade or spoil the stored items, some inert atmosphere silo is purged with nitrogen gas, to completely replace the oxygen in the system thereby suffocating any live organisms that may have accompanied the stored grain from the field into the store-house; this however result in the maintenance of the quality of the stored grain (Quezada et al., 2006). This is particularly important for sensitive commodities that are susceptible to oxidation, moisture damage, microbial growth, or insect pests. In addition, a rigid hermetic storage system can also protect against physical damage (Tefera et al., 2018). The rigid structure of the system ensures that the stored items are not subjected to external pressures or impacts that can cause breakage or damage (Odjo et al., 2020). This is especially important for fragile or delicate items that require careful handling and protection. To achieve a rigid hermetic storage system, various design considerations need to be taken into account (Williams & Rosentrater, 2022). The materials used for the construction of the system are strong and durable to provide the necessary rigidity. Additionally, the sealing mechanism is reliable and effective in creating an airtight seal. This can be achieved using gaskets, seals, or other sealing methods that are resistant to wear and tear. Overall, a rigid hermetic storage system offers a reliable and efficient solution for preserving and protecting valuable or sensitive items. By maintaining a controlled environment and preventing the entry of contaminants, it ensures the longevity and quality of the stored items. If flexible hermetic storage is not available, stiff hermetic storage composed of plastic or galvanized/stainless metals can alternatively be employed. As long as the air tightness is maintained, both of these structures may be utilized for household, retail, and commercial grain storage, as well as general fish feed storage (Oyeyinka & Adeyeye, 2016). A few examples for rigid hermetic storage system are shown in Figure 5.

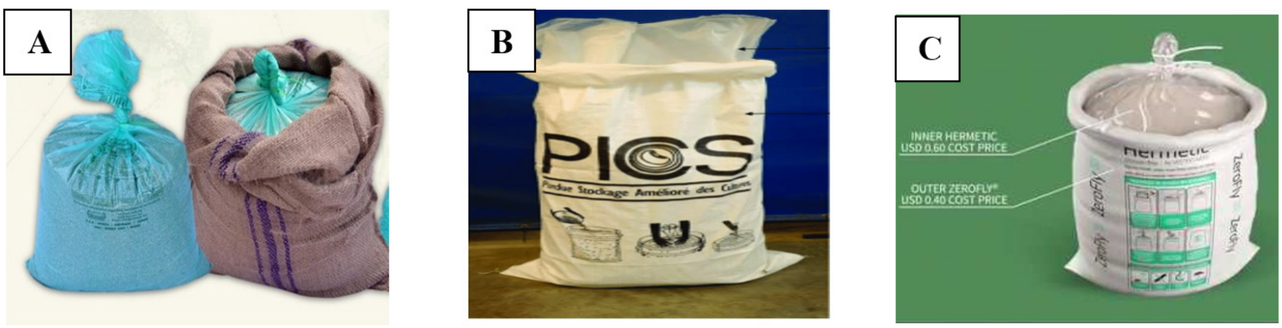

Figure 4: A: Polythene lined Jute bag, B: PIC bag and C: ZeroFly® (Source: Atta et al., 2019).

Figure 5: A: NSPRI's Hermetic Steal Drum, B: plastic hermetic rubber, C: Experimental Silo. Image taken by: N.F. Okparavero (Nigerian Stored Products Research Institute, NSPRI).

CONCLUSION

Low seed quality under long-term storage is a result of inadequate storage facilities that expose seeds to deterioration. Many of the traditional structures mentioned have limitations, particularly in durability, protection against moisture, and ambient air. Losses are incurred from plant pests causing deterioration, discoloration, and loss of nutrients, mold development on crops due to inadequate drying, pilfering by people, and shattering of grains due to premature harvest. Hermetic storage systems have significant economic importance as they contribute to reducing post-harvest losses, maintaining product quality, and improving food security for farmers. These systems offer a chemical-free and cost-effective approach to pest control during storage, leading to economic benefits for farmers and improved food and nutrition security. However, further research and development are needed to address challenges related to availability, cost, and durability to make hermetic storage technologies more accessible to smallholder farmers in developing countries.

ACKNOWLEDGEMENT

Assistance given by Dr Grace O. Otitodun, Jimoh Medinat and Rukayat Adegbola Queen during manuscript preparation is deeply acknowledged.

DECLARATION OF CONFLICT OF INTEREST

The Author has no conflict of interest relating to this article

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