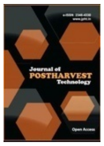

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REVIEW ARTICLE

Causes and management of postharvest losses in Nigeria: an overview

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ABSTRACT

Simple, moderate and advance storage technologies exist and are available in Nigeria with the aim of providing food materials all year round and preservation of nutritional quality and quantity with additional benefits to the country food security sustainability. The quest for global food security through healthy food, affordable and sound using available storage technologies and postharvest losses management could be a major breakthrough nationally using simple to moderate or complex storage technologies based on availability and accessibility by the value chain actors. Improved production technologies must be couple with good storage technology to curtail postharvest losses and food insecurity. Affordable technologies that can be handled by farmers from the subsistence level up to large scale production for the storage of durables crops, perishable crops and semi perishables for farmers/companies exploitation and sustainability have been developed and are in usage in Nigeria to address food insecurity despite that few storage technologies and recent advances in postharvest loss management were inadequate. Quantitative and qualitative losses and wastage of food is a major challenge in Sub Sahara Africa (SSA) which can be tamed through improved usage and popularization of sound storage technologies and good postharvest losses management. This paper review highlight and review available storage technologies and implication of postharvest losses management in Nigeria with emphasis on the usage of sound storage technologies to ameliorate postharvest losses in Nigeria..

Keywords: Domestic, large scale, postharvest losses, storage, sub-sahara Africa, traditional storage

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INTRODUCTION

The quest for healthy, affordable and sound food is the current efforts made in policy and framework of the millennium development goals (MDGs) which has been championing by many governmental and non-governmental organizations (NGO). Major causes of postharvest losses in the tropics can be attributed to premature harvesting or late harvesting, under or over drying, poor and unsecured storage facilities, poor processing tools and equipment, poor transportation mediums, and unavailability of financial supports (Abimbola and Ologan, 2021) . Postharvest prevention of food spoilage and increasing shelf-life of food grain and vegetables is tied to increasing food without significant degradation in quality with the use of appropriate advanced and improved timing of harvesting. Harvesting grains or vegetables prematurely results in poor taste,

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low flavour and low nutritional quality. However, harvesting late results in high postharvest losses in most grains such as shattering, pest attacks and reduce the germination quality of the grains. In vegetables, the produce became coarse, fibrous and spoilt easily (Gordon et al., 2010). Under drying in many crops results in poor storage, fungal development and sprouting of the produce; whereas over drying can results in weaken embryo, high postharvest losses and losses of produce from pest and contamination of the produce. The important function of any storage structure is to offer high protection from insect, pests, rodents, birds and be able to provide hermetic conditions to the stored products as well as easier to fill and empty it when the need arises. Storage structures are regarded as most important factor in handling and storage of grains and vegetables (Bucklin et al., 2013). Farmers require facilities to handle and store their produce at the end of the harvest for consumption or withholding for market when the price appreciate. Most of the losses in grains occur in storage because of poor resources of the farmers. High construction costs of storage structures results in farmers preference to use cheap, inadequate structures to store their grains (Obetta and Daniel, 2007). The intensification of food production and the surplus grain needs sound storage to preserve its nutritional quality, makes it available and accessible all times round. The need to improve the storage technology and bring forth popularization to small scale farmers to reduce unnecessary loss has become the focus of many national, international governments and non-governmental organizations. Modern storage technologies that are available and accessible by small scale and large medium farmers are now gaining ground to avoid the use of chemicals which has pesticide residue beyond acceptable limits. Thus; the concentration used of those pesticides at farmer's level and at commercial level in the storage is usually more than the allowed concentration as these caused great concerns (Ashamo et al., 2021). Storage varies with the length of time ranging from short-term storage on farm for drying to long-term storage for strategic reserves. That is, storage can occur on farm, at home or at large commercial facilities as reported by Bucklin et al. (2013). The production of different types of grains and vegetables are constantly increasing due to implementation of advance production practices and smart handling but because of improper storage facilities and poor handling practices, large amount of grains and vegetables has been spoiled most especially in sub-Saharan Africa (Singh, 2010).

Availability of food for the consumers can be increased with increasingly advance of sound available storage practices and intelligent post-harvest management practices. (Kimatu et al., 2012). Lack of available storage, poor and inappropriate storage caused contamination in the food grain leading to food losses or wastage most especially in the tropics. Losses during storage depends upon several factors such as poor handling and storage structures, wrong timing at harvesting for perishables, poor postharvest treatments of grains and vegetables before and after storage. Insects, rodents and micro-organisms also hamper the quantity and quality of the stored food grains and vegetables as reported by Sashidhar et al. (1992).

According to Singh et al. (2017), the types of storage structures and storage management have a very vital role for preserving the quality and quantity of agricultural produces. However, small scale farmers in SSA still use ancient storage structures and orthodox methods of handling perishables. The need of food storage arises due to the supply of food grains to the consumers and farmers family in the off-season or time of requirement so as to bridge the gap between production and consumption. However, main cause of contamination and deterioration of grain quality is improper storage conditions climatic conditions including increased dampness during high relative humidity or when grains were not properly dried to safe moisture level, high temperature in the tropics which favors insect's proliferation, and pockets of moisture inside the structure (Williams, 2004).

AVAILABLE STORAGE TECHNOLOGIES IN NIGERIA

Different storage technologies exist and are in use in Nigeria ranging from inexpensive to expensive ones which has a direct effect on the farmers choice, availability and cost analysis. However, any storage effectiveness depends on the exclusion of air gaining access to the storage structure (asphyxiation) which causes suffocation of the insects and at the same time maintaining safe moisture content of the grains (FAO, 1985). In perishables, the use of high relative humidity to almost 90% or above, protection against vermin and mechanical injury can increase the shelf life of the products. Report by Singh et al. (2017), suggested that storage of different food commodities required scientific and modern approach because the food commodities undergo a biological activity and perform respiration which leads them to perform a lot of metabolic and enzymatic activities. Factors that usually affect the farmers' choice of the storage methods include the cost of building the storage method, availability of the materials, expertise for building the storage facility, climatic conditions of the area and the types of pest problems in the area (FAO, 1985). In West Africa, farmers store their crops at homes, on the field, in the open, jute or polypropylene bags, conical structures, raised platforms, clay structures and baskets (Addo et al., 2002).

Simple available storage technologies in Nigeria

Most of the simple and available storage technologies in Nigeria lack security (rodents and insect proofs), air tightness and insect resurgence. Those technologies were locally used or inherited or fabricated and held temporary grain for a short period of time. Adejumo and Raji (2007) reported that, the prominent storage structure found in the Sudan Savannah includes rhumbus, bags, metal and plastic drums, warehouses and underground pit. The structure found in the guinea savannah zone includes rhumbus, warehouses, cribs and earthen pots; while in the southern rain forest zones, the structures includes mud rhumbus, maize crib, platforms, domestic or indoor storage such as plastic containers, gourds, earthen pots and metal container (Chandrasekaran et al., 2009). Other storage structures includes bags made of jute, hessian, polyethylene or plant fiber. The bag storage has been found to be convenient for bulk storage of shelled or threshed grains as the bags are very convenient in transporting the grains either from various farms, to various houses or to the markets (FAO, 2014).

Traditional storage for grains

Lack of good and adequate storage facilities remains the major factor responsible for seasonal food shortages and post-harvest losses in Nigeria with consequent seasonal hike prices of food items and food losses (Omorogie,1990). Besides quantitative losses, qualitative losses also take place which result in loss of nutritive value of the grains. These postharvest losses however can be reduced to a considerable extent by understanding the basic principles involved in the design and construction of storage structures. Effectiveness of the storage structure depends on its ability to perform the specific functions of protecting its contents on the basis of structural stability and fitness as well as having facilities for meeting operational requirements of protecting grains during the period of handling (Okunade and Barau, 2013).

On-Farm storage

This type of storage is rarely in practice now where farmers after harvesting their grains such as maize, sesame and groundnut were kept on the farm for almost 4-5 months before threshing them (Onyeniran, 1986). In some areas in northern part of the country, those products are processed with the approach of rainfall. Its free and do not require any major practices, insecurity/ pilferage and theft, nomadic and farmer's clashes have discouraged these storage practices.

Earthen ware granaries (Rhumbus)

This storage is the most common type and found of granary used in Northern part of Nigeria for storing sorghum, millet and similar crops in an unthreshed form (figure 1). Its advantage is that it is simple, made from locally available materials (Benson et al., 2021). The major challenge of this earthen ware granaries were, lack of technical structure and flexibility to protect the grain against insects, rodents, pilfering and sometimes negligence may occur which allows rainfall to enter when the lid thatch was not put in place. However, an improved version has been made by the Nigerian Stored Produce Research Institute which provides rodents guard, impervious and air tight for fumigation and provision for offloading and raising it off ground to prevent moisture and rodent entrance, Karthikeyan et al. (2009).

Figure 1: Localised Earthen ware granaries (Rhumbu) (Credit : NSPRI)

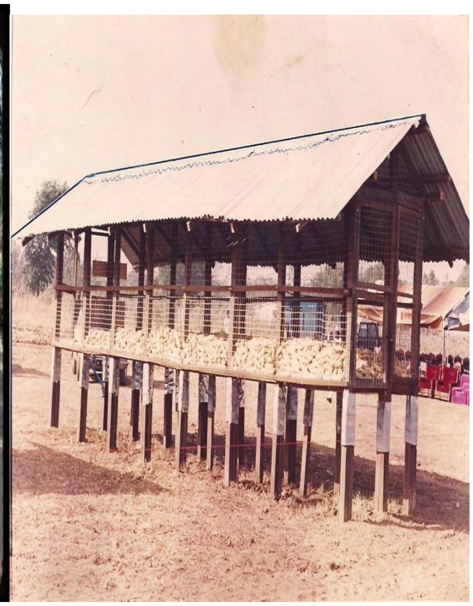

Figure 2a and 2b: Cribs for storing grains (Credit : NSPRI)

The crib

This is usually rectangular in shape and consists of firmly erected poles made of metal or woods carrying a strong compartment, covered with an asbestos roof (figure 2a and 2b). The cribs have an advantage and serve dual purpose of further drying the product and temporary storage (Shahidhar et al., 1992). Farmers can attend to other agricultural activities where they experience a bimodal rainfall. Grains such as maize can be stored at high moisture content between 20-25%, thus allowing for other agricultural activities to farmers, Olusola et al. (2021). The crib is mostly used in the southern part of Nigeria for storage of maize cobs, but its use can be extended to the storage of other crops such as millet and sorghum on head in the middle belt of the country.

Underground or Pit Storage

This type of storage is practiced in the North-Eastern part of Nigeria. This method of storage is used in dry regions because the water table does not endanger the grain. However, the ground, walls and the side walls are filled with the stalk to reduce moisture migration. This storage structure can take months and sometimes years of storage. Mishra et al. (2012) reported that, storage of grains in pits usually vary in capacity from a few hundred kilogrammes to 200 tonnes. The underground pit vary from region to region: they are rectangular, square or usually cylindrical, spherical or amphoric in shape. The entrance to the pit may be closed either by heaping earth or sand onto a timber cover, or by a stone sealed with mud or level with the ground as a disguise against pilfering.

Traditional storage for fruits and vegetables

Fresh fruits and vegetables shrivel and stale lowering their market value and consumer acceptability. Losses of fruits and vegetables can range from 30-50% sometimes up to 70% or more depending on the level of handling (Ndirika, 2002). Minimizing these losses can increase their supply without bringing additional land under cultivation. It will also help keep pollution under control and divert available resources to other means of production. Fruits and vegetables deteriorate rapidly due to their high moisture content. Therefore the moisture content of the produce itself as well as the moisture content of the surrounding air is important for keeping the product safe for storage. Respiration used up oxygen and produces carbon dioxide, water and heat as by-products. The rate of respiration and thus the amount of carbon dioxide, water and heat are strongly dependent on the temperature and moisture content of the produce.

Evaporative coolants

The design of evaporative coolants is based on the cooling effect of the evaporation of water from a wetted surface exposed to air flow within the holding structure (figure 3). Those coolants use zero energy and are able to hold the perishables in as much as that the products are free from mechanical injury, dirty and microbes for some few weeks. The products should be harvested at early hours of the morning and allowed to cool off, reduce respiration heat load and climacteric separated from non-climacteric (Onyekwelu and Aror, 1984). They can hold a perishable produce for a period of 2 weeks or even more among the commonest one were: Pot in a pot, Metal in a pot and Metal in block, and Block in a block. In each of these evaporative coolants, the spaces within the cavity created between two walls of the storage structures are filled with river bed sand and kept regularly wet by sprinkling of water. The use of evaporative cooling for tomato fruits has been reported by Abdul-Rahaman et al. (The frequency of wetting depends on the rate of evaporation of water from the outer surfaces.

Evaporation of water over the outer wall generates the desired cooling effect within an enclosed cool chamber. Care should be taken to prevent water from sedimenting in the cooling chamber.

Figure 3: Evaporative coolant (Pot-in-pot) (Courtesy: NSPRI)

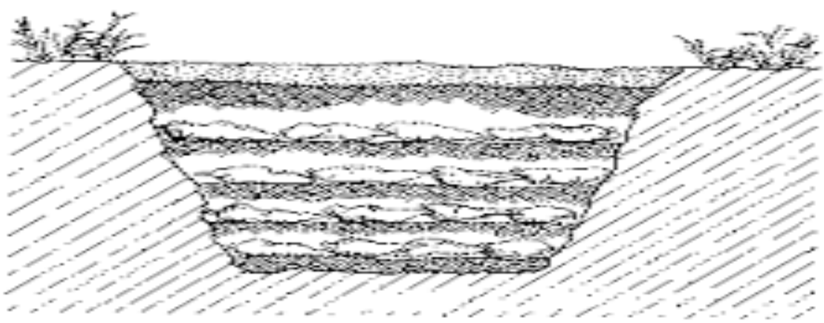

Figure 4: Cassava trench (Credit: FOA)

Trench

A trench is dug according to the need of the farmer, however it could be constructed in a rectangular or square in shape with varying measurements and layer of palm prongs or raffia leaves are laid on the bottom of the trench (figure 4). Non-bruised cassava roots are arranged on top of palm prongs while another layer of palm prongs is placed on the cassava root. The process will be repeated until the trench is filled with cassava. The entrance to the pit may be closed either by heaping earth or sand onto a timber cover. The top layer is kept moist by watering with clean water at regular interval. In this method, cassava roots can stay for 4-5 months (Mishra et al., 2012).

Vegetable baskets

This storage structure is constructed with raffia material which is flexible plant material and inner and outer wall are lined completely with jute sack. The outside of the jute thereafter will be wetted regularly to conserve freshness, cool the produce and reduce respiration heat load. The interior space of vegetable basket generates the coolness and the high humidity generated surround the content extended its shelf life to about 10-14 days (Salahudden et al.,2012). The basket is suitable for leafy vegetables, cabbage, garden eggs, and okra

Fruit shade

Fruits shades are temporary storage structures constructed on farms to provide rapid dissipating of respiration heat load cool by the perishables (Dvizama, 2000). They are constructed to provide cool and well ventilated handling space, serve as collection point for commodities to enhance handling after harvest and for temporary storage. Bamboo poles are used for construction of the framework and sides respectively whereas the roof is constructed from grasses or raffia materials.

Moist Saw Dust Boxes

A wooden box of 1.2m x 0.9m x 0.6m in dimension is constructed and a saw dust is spread at the bottom of the box which has some side perforations (Babarinsa and Oluwalana, 2018). Non bruised cassava roots with a small stem attached is then arranged inside the saw dust which is moist with water; another layer of cassava root is arranged on top of the saw dust separating the first layer. This procedure is repeated until the box is filled with cassava roots. The top layer is properly covered with moist saw dust and kept under shed. Cassava stem can last up to 2-3 months in a fresh form (Olaleye et al., 2013). The major problem of this structure is once an infected roots is introduce into the structure, rotten and infection is imminent and high rainfall areas cannot practiced this structure.

Yam Barn

This is a ventilated shed used in storage of yam (figure 5). The side of the shed is made of smooth walls of about 1.2m high, wire mesh and rodent guards are put in place to prevent rodents and birds entering. The roof is made of thatch or asbestos to keep the inside of the shed cool. The non-bruised and undamaged tubers are arranged on slatted flat farm or shelves in such a way that sprouting can be detected and removed. Yam stored under this shed can last for 5-6 months (www.bournemouth.ac.uk).

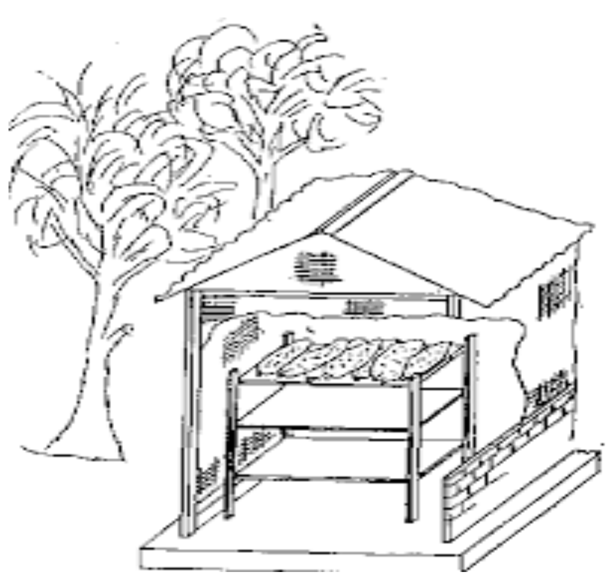

Figure 5: Improved yam barn (Credit: FAO) **Local yam Barn (Credit: bournemouth.ac.uk)**

Domestic Grain Storage

Storage of food grains enhanced the opportunity of obtaining higher price during off season. Storage of grain is treated as first step to preserve the food grains because the industries are usually demanding good quality of raw materials like grains and seeds for manufacturing, processing and final consumable products. Regular inspection and quality control practices during storage are important necessity to minimize the stored grain damage and facilitate the sufficient supply to home and industries for further usage. Grains for domestic storage are usually kept in containers that are airtight and sometimes inaccessible by insects (Singh et al., 2017).

Sacks

Where sacks are used for domestic grain storage, the bagged grain must be kept off the ground to prevent spoilage by moisture adsorptions, termites or rodents. Pallets, low platforms, tarpaulins or plastic sheeting may serve this purpose; but if there is a risk of damage by rodents or other animals, high platforms fitted with rodent barriers should be used. If there is a risk of rain during the temporary storage period the bags should be covered with waterproof sheeting unless the grain has moisture content much in excess of 12% (Baributsa et al., 2015). Alternatively, the sacks of grain should be stacked on pallets or waterproof sheeting, away from walls. The need for chemical methods of pest control should not arise because triple bagging have improved the way product are kept devoid of insects infestations and no pesticide residue (Singh et al., 2017). The principle triple bagging is shown in figure 6

Figure 6: Purdue Improved Crop storage (PICS)

Metal or Plastic Drums

To make a store of greater capacity, two metal drums can be welded together end to end and fitted out. Metal drums can also be made airtight (figure 7). Inaccessible to rodents, efficient against insects, sealed against entry of water, drums make excellent grain containers. However, they should be protected from direct sunshine and other sources of heat to avoid condensation. It is therefore better if being located in shaded and well ventilated places. Mishra et al. (2012).

Figure 7: Metal and plastic drums

Earthen Pot

The earthen pot storage is found in very few villages in Kaduna and Kano States in Nigeria. It is made of burnt clay. The shape and sizes differ with the locality. They have capacity of between 5 – 20kg of threshed or shelled cereals as reported by Adesina et al. (2019). The grains stored in this pot are used mainly for seedlings. The grain stored includes cowpea, maize and sorghum. However, damages to seed may include rodent attack, mould growth, sprouting; seed may change color, odor and taste as the result of moisture (Adejumo and Raji, 2007).

Synthetic Silo

Those synthetic polyethylene plastic are gaining adoption as a means of storage structure in Nigeria. The outlet is usually sealed hermetically where the inlet is covered with high density polyethene for storing grains most especially cowpea. The synthetic silo should be kept under lower temperature to deter insect's damages due to their metabolic activities, CFTRI, (1975).

Commercial Grain Storage

Modern storage structures are now gaining popularity for used in holding larger grain capacity suitable for large scale bulk storage. They are used by state and federal government for their strategic grain reserve project. Traders, industrialists, cooperatives and central storage depots and some number of large scale farmers are using the storage. The storage structures are silo bins, modern underground pit, warehouses (stores) and inert atmosphere silos (Bogaard et al., 2009).

Steel Bins

Those are cylindrical bins standing upright and are usually constructed using metal sheets. They are expensive and may require handling equipment such as conveyors, dryers, and fans. Storage in silos is very effective, but with poor management, there is risk of rapid and total loss of grains through moisture condensation, mold growth and insect infestation. Steel bins should be galvanized, and the bolts and nuts zinc coated; rust-protection paint should be applied when rust spots appear. The outside walls of concrete silos require a protective coating occasionally to prevent the damaging effect of environmental sulfurous air-pollution (Mijinyawa, 2010).

Warehouses

Commodity store has been adopted for medium to large-scale storage of grains in bags and is currently being recommended for use on farms (figure 8). The effectiveness of the store depends largely upon the adequacy of the design, construction and utilization. The store should be properly cleaned and disinfected before putting in the bagged grains. The bagged grains should also be properly disinfected using phosphine gas as fumigant. The bags should also be arranged on pallets or dunnages in the store following recommended arrangement pattern. On no account must insecticides or chemicals not recommended for grains storage be allowed to come in contact with the grains. It may also include materials and equipment required for the packaging and handling of bagged grain, and means to control storage pests. Factors such as topography, soil characteristics, accessibility, orientation and proximity to human dwellings should be considered when locating the warehouse (Naik and Kaushik, 2011).

Figure 8: A sealed door of stored grains warehouse at Dawanau International Market, Kano State, Nigeria

Controlled Atmosphere Storage

Controlled Atmosphere storage system is a technique of preserving food grains in atmosphere of which the gaseous composition of normal atmosphere has been altered. The storage atmosphere is thus manipulated to give a mixture of gases which is capable of controlling the development and effects of quality degradation agents in the stored commodity. No aerobic organisms can survive in an oxygen deficient atmosphere. Hence, all insect pests that are responsible for postharvest spoilage of grains cannot survive and will consequently die without any further damage to the stored grain (Hatice, 2016).

POSTHARVEST LOSSES MANAGEMENT

The gentle use of harvesting and handling tools would help avoid cuts, abrasions, and bruising damage that allow opportunistic micro organisms to proliferate into the product tissue in fruits and vegetables. Harvest produce at the peak of its quality, these minimize insect attack and assure greatest value of the produce at the time the commodities are offered for sales or storage period for later sale. Most produce begin to deteriorate at the time of harvest, the highest-quality produce will have the greatest shelf life. During harvesting, always harvest at the cool part of the day. Because temperature controls the rate at which produce deteriorates, harvest when the temperature is cool usually just after sunrise as this will extend their quality by reducing respiration heat loads, cool down the produce, reduce high metabolic activities and enzymatic activities. Where storage facilities are not adequate, harvest only as much produce at one time as you can pack or sell before the quality deteriorates, this will ensure fresh and highest quality available to customers and obtain good price. Use trees or organic materials shade cover immediately after picking fruits or on field wagons, trucks, and market areas. Hold produce in a shaded area while awaiting packing. Perform packing operations under a shaded location to acclimatize the produce. Vegetables exposed to the sun will absorb solar energy and become warmer than those in the shade. For commodities that loose quality rapidly and those to be shipped to market, special postharvest washing, handling, and cooling are required to maintain quality. Take care to avoid bruising in transportation to the packing shed, during unloading, washing and grading (Bekele, 2021).

Wash the product with water or chlorine to remove extraneous materials such as dirt's, chemicals and latex. Precool rapidly and remove field heat from the produce to reduce the rate of respiration, field heat and microbial activity. Product should be cured to initiates the formation of periderm layers at wound areas, thereby reducing moisture loss and microbial infection. Wax the product to control excessive moisture loss and improve attraction (www.postharvest.ucdavis.edu)

CONCLUSION

The choice of storage largely depend on farmer’s purchasing power, level of education, geographical location and the intended duration of storage, quantity to be stored and available facilities for storage. Poor storage management will automatically leads to high postharvest losses. With good postharvest losses management, the losses of food will be checkmate to the barest possible. Furtherance to this, with good storage and good postharvest management, the challenges of food security and global food crisis in Sub-Saharan Africa will be a history.

RECOMMENDATIONS

Storage management is important for all types of storage functions be it traditional, domestic or large scale uses of storage. Prevent damp (moisture) from the floor and walls reaching the produce by stacking the bags on pallets off the ground and away from the walls. Damp from the roof is avoided through proper ventilation. Moisture infiltration from the floor is avoided using damp absorbing materials. Ease of sweeping the floors. Make sure the building is rodent-proof. Treat the building and protect against pests. Keep the warehouse clean. Close all holes in doors, roof, where pests can enter. Repair cracks in walls where pests can hide. Remove and destroy any infested residues that could contaminate newly introduced produce. Need for technical personnel from the lowest to the highest in storage technology could help to sensitize and popularized storage challenges in rural areas which has to be dealt with all seriousness and sincerity. Advances in storage technology should be taken to the door steps of the farmer and ensured that it is adoptable and affordable.

REFERENCES

Abdul-Rahaman, A., Alhassan, N., Tabormah, C., Dakorah, A., Addae, K. C., Aziz, M., and Iddrisu, K. A. 2015. Clay cooling pots technologies for storage of Fuzzy Bomb and Bonita Roma varieties of tomato fruits. Journal of Arid land Agriculture, 1 (1), 6-12.

Adejumo B.A and A. O Raji. 2007. Technical Appraisal of Grain Storage Systems in the Nigerian Sudan Savannah".Agricultural Engineering International: the CIGR E journal, 11. IX.

Adepoju, A.O. and Ologan, O. 2021. Post-harvest loss along the watermelon value chain in the tropics, International Journal of Vegetable Science, 27(5), 461-471.

Adesina J. M., Nameirakpam B., Dinabandhu S. and Yallappa R 2019. Traditional methods of food grains preservation and storage in Nigeria and India. Annals of Agricultural Sciences, 64(2), 196-20.

Ashamo, M.O., Ileke, K.D. and Onasile, A.I. 2021 Chemical composition and toxicity of some Agro waste-derived insecticides against Angoumois grain moth, Sitotroga ceralella Olivier) [Lepidoptera: Gelechiidae] infesting stored paddy grains. Bull Natl Res Cent, 45(25), 1-12.

Babarinsa, O.A. and Oluwalana, I.B. 2018. Effect of storage of fresh cassava in sawdust on Gari processing. Journal of Postharvest Technology, 6(1), 57-62.

Baributsa, D., Baoua I., Abdoulaye, T. and Murdock, L. 2015. A Guide On The Use Of Pics Bags For Grain Storage. Purdue Extension.

Bekele, D. 2021. Role of Postharvest Management For Food Security: A Review. Advances in Crop Science and Technology, 9 (7), 2-6

Benson, O, Afolabi A. A., Ajibade O A., Taiwo S.T., Omotuyi M.O and Okonkwo, E. 2021. Usage of Maize Storage Technologies for Postharvest Loss Prevention in OkeOgun/Saki Area of Oyo State, Nigeria. Journal of Agricultural Extension, 25 (1), 29-37.

Birkinshaw L.A and Hodges R.J. 2002. Ten years after the arrival in Ghana of larger grain borer: farmers' responses and adoption of IPM strategies. International Journal of Pest Management, 48(4), 315- 325.

Bogaard, A., Charles, M., Twiss K. C., Fairbairn A., Yalman N., and Filipovic D., 2009. Private pantries and celebrated surplus: storing and sharing food at Neolithic Catalhoyuk, Central Anatolia. Antiquity, 83(321), 629–668.

Bucklin, R., Thompson, S., Montross, M., and Abdel-Hadi, A. 2013. Grain Storage Systems Designs. In Handbook of Farm, Dairy, Food Machinery Engineering. New York, USA: Elsevier, 123-75.

CFTRI 1975. Storage of food grains. Annual Report of the Central Food Technology Research Institute, Mysore, India. p67.

Chandrasekaran, K., Veeraragavathatham, D., Karpagam, D. and Firdouse, A. 2009. Traditional storage practices. Indian Journal of Traditional Knowledge, 8 (4), 564-568.

Dvizama, A.U. Performance Evaluation of an Active Cooling System for the Storage of Fruits and Vegetables. Ph.D. Thesis, University of Ibadan, Ibadan. 2000.

FAO. 1985. Food and Agricultural Organization of the United Nations: Production Yearbook 44, Rome

FAO. 2014, Global Initiative on Food Loss and Waste Reduction. Definitional framework of food loss, Working Paper.

FAO.1985. Prevention of post- harvest food losses: A Training Manual. FAO, Rome. Agricultural development economics division Food and Agriculture.

Gordon, C.H., Derbyshire, J.C. and Van Soest, P.J. 2010 Normal and Late Harvesting of Corn for Silage. Journal of Dairy Science, 51(8), 1258-126.

Hatice, P. 2016. Cereal Storage Techniques: A Review. Journal of Agricultural Science and Technology, 6(2), 67-71.

Karthikeyen, C., Veeraragavathatham, D., Karpagam, D., and Ayisha F.S., 2009. Indiginous storage structures. Indian Journal of Traditional Knowledge, 8(2), 225–229.

Kimatu, J. N., McConchie, R., Xie, X., and Nguluu, S. N. 2012. The Significant Role of Post- Harvest Management in Farm Management, Aflatoxin Mitigation and Food Security in Sub-Saharan Africa. Greener Journal of Agricultural Sciences, 2(6), 279–288.

Minjinyawa, Y. 2010. Food and Crop Storage Technology, Farm structures. 2nd Edition. Ibadan University Press, Ibadan, Nigeria, p110.

Mishra, A., Prabuthas, P. and H.N. Mishra. 2012. Grain Storage: Methods and Measurements. Quality Assurance and Safety of Crops and Foods, 4(3), 136–158

Naik, S. N., and Kaushik, G., 2011. Grain Storage in India: An Overview. Centre for Rural Development and Technology, IIT Delhi. India, p119.

Ndirika, Victor. 2002. Storage Techniques For Fresh And Processed Fruits And Vegetables. Conference: Proceedings of the First International Conference of West African Society for Agricultural Engineering on Food Security and Poverty Alleviation in West Africa. pp:127-132.

Obetta S, and Daniel C. 2007. Preliminary investigation into some quality control indices for selected stored grain in Makurdi, Nigeria. Nigerian Food Journal, 25 (1), 117- 129.

Okunade, S.O. and Barau B. 2013. Integrated pest management (IPM) for grain production and storage. Paper presented at Federal College of Agricultural Produce Technology, Hotoro, Kano. For “Training of Extension Officers from Kano, Kaduna , Katsina, Jigawa and Bauchi state”. Nov. 2013.

Olaleye O. O., Otunola E. T., Oyebanji A. O and Adetunji C. O.2013. Effectiveness of trench andmoist sawdust as storage methods for maintenance of moisture contents and microorganisms of cassava roots by variety. Sky Journal of Food Science, 2(3), 19 – 26.

Olusola, J.0. 1986. Storage of raw and Processed agricultural product. What option? Paper presented at the 3rd National symposium of the Nigerian Society of Agricultural Engineers, held at University of Ile-Ife on the 3rd September 8-15.

Omoregie, A.U. 1989. Problems of food storage and preservation in Nigeria. Journal of Tropicultural, 8(2), 55-58.

Onyekwelu, I,U. and E. Aror. 1984: Effect, reduced agriculture on the keeping quality of green leafy vegetables (Amarathus spp.) paper presented at the NSPRI In-House Review of Research Programme

Postharvest Technology Research and Information Center at University of California, web page: www.postharvest.ucdavis.edu

Salaudeen, K., Anugwom, U., Olayemi, F.F. and Fidelis, A. 2012. Effect of NSPRI tin-in-pot compared with pot-in-pot evaporative cooler on the stored fruits. International Journal of Engineering and Technology, 2(1), 1-11

Sashidhar, R. B., Ramakrishna, Y., and Bhat, R. V., 1992. Moulds and mycotoxins in sorghum stored in traditional containers in India. Journal of Stored Products Research, 28(4), 256– 259.

Singh, V., Verma, D.K. and Srivastav, P.P. 2017. Food Grain Storage Structures: Introduction and Applications. https://www.researchgate.net/publication. Retrieved 20/12/2019

Singh, P. K., 2010. A decentralized and holistic approach for grain management in India. Current Science, 99(9), 1179–1180.

Williams, J.H. 2004. Human Aflatoxicosis in developing countries: a review of toxicology, exposure, potential health consequences and interventions. African Journal of Clinical Nutrition, 80(1), 106- 1122.

www.bournemouth.com [accessed 15th Febuary, 2023]

www.postharvest.ucdavis.edu [accessed 20th March, 2023]