Review

The challenges of grain storage: a review

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ABSTRACT

Postharvest losses account for about 10 per cent of the total food grains due to unscientific storage, insects, rodents, microorganisms etc. After reviewing academic and technical literature it was found that traditional approaches are also significantly important for grain storage in India. According to this study, farmers in India are also adopting modern technologies like hermetic storage and automated metal bins. The on-farm storage of grain like cover and plinth storage (CAP) technology was also considerably improved since its inception as compared to heap storage of grain. After studying the surveys of agricultural extension, it was found that metal bin is maximum used due to its low cost, easy fabrication and use. For Animal feed storage like hay, old traditional method of heap storage in open or in godowns is preferred by farmers in India. These methodologies are basically based on traditional or local consideration. In terms of advancement, environmental variables like temperature, breakage of grain, moisture etc are monitored in godowns and research for preliminary design and fabrication of bins and silos requires consideration of these environmental variables. Drying of harvested grains to safe moisture levels will reduce losses to a greater extent.

Keywords: Food security; grain storage; bin; silos; postharvest

INTRODUCTION

Conservation of biodiversity in terms of grain storage nowadays is essential due to cultural heritage and health of the state. This paper draws the attention towards the re-evaluation of traditional grain storage structures in terms of biodiversity and its allied branch of knowledge. In India as identified by Dejene et al (2004), pre-storage loss during drying and cleaning was higher than the loss during the storage. Average storage cost per quintal per year is maximum among the gunny bags lined with polythene sheet and minimum in case of underground storage. Similarly postharvest implements also cause loss in grains so only cereals are threshed by machines as compared to pulses which are threshed manually. Loss of grains during transportation was reported for tractor and bullock cart. Additional measures after threshing like sieving also caused grain loss as stated by Nwosu (2016). These losses are significantly comparable to loss of grains due to insects, rodents and microorganisms in storage. As on today 30 per cent of grains are lost due to natural contamination of food grains in India (Nwosu 2016). The use of bio-insecticide is not very effective due to biodiversity in pests and microorganisms. In prehistoric times, only damage by rodents was considered as only grain loss during storage which is significantly incorrect. Other environmental factors are also responsible for loss of grains in storage like presence of moisture, humid environment and existence of bio-temperature suits for breeding of pests and microorganism in grain storage. Atmospheric condition before and at the time of storage of grains plays pivotal role in examining the damage of grains in storage. Discoloration, emittence of smell, loss of germiability and essential nutritional and medicinal properties which remain undetected by normal human behaviour lead to loss of quality and nutritional value which results in capital loss of stored grains.

The crops generally stored in storage structures in India are jowar, maize, wheat, barley, paddy, millets, sesame, soybean, groundnut, sorghum, black gram, green gram, lintel (tur, arhar) and beans.

The typical grain storage structures found are polythene/plastic bags, fertilizer bags, gunny bags, jute bags, heaps of grains in room, metal bins, Pucci Kothi, Bukhari, Theka and underground storage.

Material and methods for grain storage

If the grains are stored in air-free environment or air tight environment they affect the metabolism of the pest and insects as happens in the hermetic storage (Bhardwaj 2015). In hermetic storage the mechanism of carbon dioxide and depletion of oxygen occur which is due to collection of carbon dioxide and depletion of the oxygen from the storage due to breathing of the grain or due to any other abiotic or biotic factors. It results in deficiency of oxygen inside the storage so the buffer of carbon dioxide and oxygen exists in the hermetic storage to allow breathing of the grain like wheat. Open sun drying and shade drying are common rural practices in India which result in the process of lowering the grain water activity and increase in kernel hardness of the grain. Total processes involved for grain storage in India are threshing, winnowing, cleaning, drying, bagging, ponding, dehusking and decotification.

The purpose and objectives of grain storage structures in India (Bhardwaj and Sharma 2019) are quantity of grains, purpose (commercial/household/seed), time period, place of storage, treatment like fumigation or disinfections, frequency (iterations from the bins/silos), frequency of the treatment, control measures and readiness like dampness, humidity, temperature etc, quality of the grain, modern measures if applied like osmosis, salt, sugar, oil, sun drying etc.

The challenges in the grain storage

The main bottleneck lies in the handling and transportation of grains. Traditionally grains are stored in bags either of jute or HDPE bags of 50 kg capacity. On-farm storage of grains also occurred in the form of cover and plinth storage instead of heap storage in older times of India. This happens during procurement operations of storage of food grains up to the evacuation and transportation to their designated areas. This system was primarily used for storage of paddy and wheat procured from the farmers. CAP storage is a time-tested technique for short term temporary storage of wheat and paddy. As per Omobowale et al (2016), CAP storage involves the construction of raised plinth of about 0.6 m (2 ft) from the ground over which stacking of bags of food grains is done in dome shape. The stacks are covered with 250 micron LDPE covers from the top and all four sides. Food grains such as wheat, maize, paddy and sorghum are generally stored for 3-6 months. It is the most economical storage structure and is being widely used in Haryana for bagged grains. The structure can be fabricated in less than 3 weeks. In India farmers keep roughly 65 to 70 per cent of the rice and wheat they grow for food, feed of animal or seed purposes and market their food grains in Krishi Mandis (government as well as of private vendors). The larger portion is retained at farm level based on the size of the farm holding, surplus of grain and holding capacity of the farmer.

Postharvest losses

Major postharvest losses occurring in grain considered by farmers are weather (40%), field damage (33%) and storage pests (16%) as the three most important factors causing poor crop yields and aggravating food losses. However survey results suggest that the farmers' poor knowledge and skills on postharvest management are largely responsible for the food losses (Abbas et al 2014). There is need for technical knowledge of the farming systems in relation to climate variability to minimize postharvest losses. Also necessary trainings on postharvest management can reduce food losses and improve poverty and household food security. As per Jain et al (2000) major physiological, physical and environmental causes of postharvest losses are high crop perishing ability, mechanical damage, excessive exposure to high ambient temperature, relative humidity, rain, contamination by spoilage through fungal and bacteria, invasion by birds, rodents, insects and other pests and inadequate handling, storage and processing techniques.

In current time contamination through mycotoxins is also found in urban areas of India. Lopez-Castillo et al (2018a) reported that mycotoxins are poisonous compounds produced by certain species of fungi found in contaminated grain. There are five major groups of mycotoxins which can occur in grains viz aflatoxin, fumonisin, deoxynivalenol (DON), ochratoxin (OT) and zearalenone (ZEN). Their occurrence may start in the field during harvesting, handling, storage and processing. To avoid this spoilage best aeration of grains must be adopted (Pattanaik and Tripathi 2016); this aeration of grains can be done by installing horizontal fan in the bins and silos. By keeping air flow rates and fan control methods, best results to avoid spoilage could be obtained for aerated wheat stored in round bins and large horizontal storages under tropical and subtropical climatic conditions. To improve food quality, ozone is a strong oxidant and has different food applications to ensure food safety. Ozone treatment is considered an ecofriendly and cost-effective food processing technique. Ozone has great potential to improve the functionalities of grain products while ensuring food safety. The impact of ozone treatment on the composition (eg mycotoxins) and physico-chemical properties of components (eg starch and protein) of different food grains (eg wheat, rice and maize) has been studied by Zhu (2018) who concluded that the rheology, colour, storage and germination capacity of the grains are affected by ozone. Besides spoilage, presence of moisture content and broken kernels in postharvest grains effects the initial bulk density of the grain and grain compaction under overburden. For grains, the initial bulk density is inversely affected by grain moisture while packing increases slightly with grain moisture. If we consider the increase in broken kernals of the grains, this initial bulk density of grain decreases further with the grain moisture and the interaction of broken grain particle size and concentration results in increased volume of grain storage (Ruiz et al 2012).

Similarly effect of temperature, relative humidity and moisture content on germination percentage of grain stored in different storage structures is also significant (McNeill et al 2013). In the grain storage structures grain moisture content increases as compared to ambient moisture. Similarly temperature in grain storage structure also gets increased as compared to ambient temperature. It has been observed that germination percentage of the grain decreases in all the grain storage structures despite the fact of increase in relative humidity inside. This happens due to inadequate aeration system in the grain storage system.

Postharvest losses due to pests

To increase the resistance against pests in grain has nowadays reached its new heights for example in maize research the possible application of peroxidases as a breeding trait for the development of maize varieties increases resistance to storage pests (Lopez-Castillo et al 2018b). Similarly antibiosis, antixenosis and preference were the mechanisms of maize grain resistance to *Sitophilus zeamais* attack. Neme and Mohammed (2017) identified crude fibre, phenolic acid and trypsin inhibitor of whole-maize grain as the bases for resistance. Their significant increase in grains resulted in low infestation.

However our knowledge about natural resistance to pests is still limited. The specific function of biochemical factors such as peroxidases and phenolic acid amides remains undiscovered. Wider and deeper research in this area is necessary in order to better inform future breeding programmes. This knowledge will be fundamental in future breeding programmes contributing to reduction of postharvest insect losses of food and global food security with special interest in vulnerable countries (Kapur et al 2011).

Efficiency of components of storage

In the Krishi Mandis in Haryana and Delhi, inadequate aeration rate and absence of fan control were found in all the grain storage systems. There is less or no control on grain moisture, ambient temperature and relative humidity in grain storage in India. This draws attention towards improved measures for grain storage in India to minimize the postharvest loss of grains.

Hosakoti et al (2013) reported that the construction of suitable sensors for online monitoring of grain moisture and grain temperature inside the storage structures is recommended for evaluation of grain temperature and grain moisture at different locations within a storage structure together with ambient temperature.

Encouragement to solar power in the components of grain storage is strongly recommended and their controlling mechanism through environment variables is preferred as an example use of humidistat to control solar powered DC fan for grain drying (Sinicio and Muir 2013). A low cost, low energy microcontroller-based humidistat was constructed to control the operation of a photovoltaic driven DC fan. Fan current and voltage, insulation, ambient temperature and relative humidity were recorded at five minutes intervals to test whether the humidistat performed as expected.

While designing the storage system, drying temperature, drying time and cooling type were the main factors in predicting mass flow rate in the storage system (Bhadra et al 2017).

Design and fabrication of components of storage

Hermetic storage containers such as metal silos (soldered airtight) and super grain bags (made from high density polyethylene to reduce gas exchange) may enable farmers to reduce postharvest losses.

While the metal silos are very effective they are also expensive. Because half of their cost comes from the metal sheet, the cost per kg of grain stored decreases with the volume of the container. Therefore economic analysis is needed to determine the size at which silos become economical under different price conditions (de Groot and Mazur 2013).

Considering the inadequacy of grain storage structures, which has been partly attributed to high cost and unavailability of construction materials, the suitability of using readily available termite mound clay (TMC) for grain silo construction in comparison to conventional reinforced concrete (RC) and galvanized steel (GS) silos for grain storage in the humid tropic is suggested (Omobowale et al 2016).

In underground pits, the grains acquire moisture from the surroundings which becomes cause of development of insect pests and storage fungi in underground ground storage for sorghum grain (Dejene et al 2004).

System of the silo-hopper storage

While analyzing the pressure theory of the silo and the mechanics of storage, Ruiz et al (2012) explained that in designing of silo irrespective of dimension, shape and material, only two types of pressure is consistently working. First is the normal wall pressure and second is the vertical pressure of the stored material. This normal wall pressure is generated during the filling and emptying of the silo. It is not held constant during the emptying and filling of the silo. Its mechanics requires detailed study especially during surge inside the silo. However this normal pressure decreases over the long storage period due to release of frictional forces. The horizontal thrust of the grain material is independent of these two pressures. The universal mechanics can be written as below for silo normal wall pressure:

$$\text{Silo normal wall pressure} = \frac{\text{Frictional force of the grain on the wall}}{\text{Surface area of the wall on which it is acting}}$$

Similarly vertical pressure exerted by the grain material is maximum when silo is completely filled and its distribution is almost held constant during static conditions. Subsequently it decreases during emptying of the silo. So the universal mechanics can be written for silo vertical pressure of the stored material as shown below:

$$\text{Silo vertical pressure} = \frac{\text{Specific weight of the grain x volume of the grain in the silo}}{\text{Unit of length at each time (t) x perimeter of the silo}}$$

These pressures are susceptible to biophysical phenomena and environment; these pressures keep changing with respect to surge in the silo and change in the dimension of the silo and hopper.

CONCLUSION

Current research is not sufficient to explain each and every phenomenon occurred in the grain storage. Challenge in the insect and pest management can be dealt comfortably with the help of entomological and biotechnological tools and research.

Similarly storage environment suitably improves and conveniently changes with the help of modern tools of computational fluid dynamics (CFD). The material properties and their impact in terms of variation of stress during emptying and filling of grain storage can be easily studied through finite element method (FEM) tool and its related technology. With the help of FEM, design of the material and structure are considerably improved and are monitored with the help of electronic sensors if these electronic sensors data are correctly and appropriately fed into these CFD and FEM tools to process the design change and flow characteristics of the grain. With this the postharvest losses of the grain can be minimized up to the zero level and grain quality is also intact by keeping electronic sensor data correct and accurate.

REFERENCES

Abass AB, Ndunguru G, Mamiro P, Alenkhe B, Mlingi N and Bekunda M 2014. Postharvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. Journal of Stored Products Research **57:** 49-57.

Bhadra R, Rosentrater KA and Muthukumarappan K 2017. Modeling distillers dried grains with solubles (DDGS) mass flow rate as affected by drying and storage conditions. Cereal Chemistry **94(2):** 298-309.

Bhardwaj S 2015. Recent advances in cover and plinth (CAP) and on-farm storage. International Journal of Farm Sciences **5(2):** 259-264.

Bhardwaj S and Sharma R 2019. The success of grain storage system. In: Proceedings of the National Seminar on Biodiversity: Issues, Challenges and Opportunities, 16-17 July 2019, CCS HAU Hisar, Haryana, India, pp 49.

de Groot SR and Mazur P 2013. Non-equilibrium thermodynamics. Courier Corporation, 528p.

Dejene M, Yuen J and Sigvald R 2004. The impact of storage methods on storage environment and sorghum grain quality. Seed Science and Technology **32(2):** 511-529.

Hosakoti SS, Dolli SS, Hiremath US and Angadi JG 2013. Methods of storage of grains by farmers and losses during storage. International Journal of Agricultural Statistical Sciences **9(1):** 235-239.

Jain SK, Sivadasan K, Murty SN and Rai AK 2000. A personal computer-based monitoring system for safe grain storage. Journal of Agricultural Engineering **37(2):** 27-38.

Kapur D, Lewis JP and Webb RC 2011. The World Bank: its first half century: Vol 1: History (English). Brookings Institution Press, Washington, DC.

Lopez-Castillo LM, Flores-Rivera FMD, Winkler R and Garcia-Lara S 2018a. Increase of peroxidase activity in tropical maize after recurrent selection to storage pest resistance. Journal of Stored Products Research **75:** 47-55.

Lopez-Castillo LM, Silva-Fernandez SE, Winkler R, Bergvinson DJ, Arnason JT and Garcia-Lara S 2018b. Postharvest insect resistance in maize. Journal of Stored Products Research **77:** 66-76.

McNeill SG, Thompson SA and Montross MD 2013. Effect of moisture content and broken kernels on the bulk density and packing of corn. Applied Engineering in Agriculture **20(4):** 475-480.

Neme K and Mohammed A 2017. Mycotoxin occurrence in grains and the role of postharvest management as a mitigation strategies: a review. Food Control **78:** 412-425.

Nwosu LC 2016. Chemical bases for maize grain resistance to infestation and damage by the maize weevil, *Sitophilus zeamais* Motschulsky. Journal of Stored Products Research **69:** 41-50.

Omobowale MO, Armstrong PR, Mijinyawa Y, Igbeka JC and Maghirang EB 2016. Maize storage in termite mound clay, concrete and steel silos in the humid tropics: comparison and effect on bacterial and fungal counts. Transactions of the ASABE **59(3):** 1039-1048.

Pattanaik BB and Tripathi RK 2016. Grain storage research: handling and storage of food grains in India. Indian Journal of Entomology **78(Special):** 17-27.

Ruiz A, Couto A and Aguado PJ 2012. Design and instrumentation of a mid-size test station for measuring static and dynamic pressures in silos under different conditions: Part II: Construction and validation. Computers and Electronics in Agriculture **85:** 174-187.

Sinicio R and Muir WE 2013. Aeration strategies for preventing spoilage of wheat stored in tropical and subtropical climates. Applied Engineering in Agriculture **14(5):** 517-527.

Zhu F 2018. Effect of ozone treatment on the quality of grain products. Food Chemistry **264:** 358-366.