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Evolution and trends in food grain storage in India

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ABSTRACT

Food grain is the major source of energy for human and cattle in the developing countries. Post-harvest grain losses are caused by biotic (insects, mold and other bio-agents) and abiotic (moisture content, heat and humidity etc.) factors. The post-harvest losses in cereals, pulses and oilseeds have been reported to be in the range of 3.9–6.0%, 4.3–6.1% and 2.8–10.1% respectively. The inputs (land, water, seeds, chemicals, energy etc.) used to produce the grain are also wasted, when we are unable to prevent food grain loss. The overall objective of grain storage is to preserve the quantity and quality (including nutritive value) of grains. The successful implementation of grain storage technologies can reduce post-harvest losses in grains to as low as 0.1–0.5%. In India, we have three distinct end users for storage of food grains. These are farmers, processing units and government. The capacity of storage structures required for farmers ranges from 0.5 to 2 tonnes. The farmers use different kinds of traditional structures, metal bins and bags for storage of food grains. The agro-processing industries such as rice mills, oil milling units, roller flour mills, pulse mills store grain to meet their processing requirements. The requirement of storage by majority of such units ranges from 1,000 to 20,000 tonnes. Government agency Food Corporation of India (FCI) is engaged in procurement, storage and distribution of wheat (*Triticum aestivum* L.) and rice (*Oryza sativa* L.). Around 30% of wheat and paddy produced every year is procured by the Food Corporation of India (FCI) and most of it is stored in warehouses by the FCI. Pilot projects on bulk storage of food grains have been initiated by the FCI. The agro-processing industries are more inclined in favour of bulk storage structures for food grains, as it saves space in processing unit and also the operations such as loading/unloading, fumigation and aeration of grain bulk can be mechanized. This paper highlights the grain storage by farmers, commercial storage of grains by government and agro-processing industries, recent developments in storage structures, cost comparison of different systems for storage of food grains, quality control, preventive treatments and various government schemes for increasing capacity of storage for food grains.

Key words: Aeration, Bulk storage, Fumigation, Metal bins, Post-harvest loss, Storage structures

Grain storage is a practice which is followed worldwide. In India, grain procurement, storage and distribution is done primarily by the Food Corporation of India. At present, only 30% of the total food grain production is handled by organized sector. The storage capacity available with the FCI is around 28 million tonnes, which includes hired capacity from Central Warehousing Corporation (CWC) and State Warehousing Corportations (SWCs); in comparison to the present requirement of approximately 60–70 million tonnes. Around 3 million tonnes of food grain is stored temporarily under cover and plinth (CAP) storage for short duration in procurement areas. The storage infrastructure in India is just sufficient to tackle present production of food grains. The available infrastructure lacks in facilities for sanitation, mechanized loading/un-loading, aeration, fumigation, monitoring etc. Recently, bulk grain storage facilities have been created at Moga, Punjab and Kaithal, Haryana. The storage structures at farmer's level mainly constructed from mud, bamboo, stones, and plant materials are neither rodent-proof, nor secure

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from fungal and insect attack. Various research and development organizations in India have identified some proven, age-old structures from certain areas of the country and based on these, some improvised storage structures such as coal tar drum bin, Hapur bin, PKV Akola bin, PUSA bin, metal bin etc. have been developed and recommended for use at farmer level. The capacities of these bins are up to 1,000 kg. Under the umbrella of *Grameen Bhandaran Yojana,* a total of 24,706 godowns in rural areas have been built with a total capacity of 28.3 million tonnes, till March 2011.

The grains need to be stored safely until consumed. A stored grain bulk is a man-made ecological system in which deterioration of the stored product results from interactions among physical, chemical, and biological factors. The important factors are: temperature, moisture, carbon dioxide (CO_2), oxygen (O_2), grain characteristics, microorganisms, insects, mites, rodents, birds, geographical location, and granary structure. The storage life of grains depends mainly on two physical factors: temperature and moisture content. The survival and reproduction of biological agents in grain are dependent to a great extent on the temperature and moisture levels. Stored-product insects can live at temperatures from 8º to 41°C and inter-granular relative humidity's (r.h.) from 1 to 99%. Usually development and multiplication are optimum near 30°C and 50–70% r.h. but stop at 18^{o}C. Mites can live at temperatures from 3º to 41°C and r.h. from 42 to 99% with the optimum for development and multiplication near 25°C and 70–90% r.h. Fungi can develop at temperatures from 2º to 55°C and r. h. from 70 to 90% with the optimum temperature near 30°C, and r.h. around 80%. There is considerable variation in optimum conditions for different species. Localized regions may occur in stored-grain bulks for optimum development and multiplication of insects, mites, and fungi even when the average conditions of the bulk would prevent pest infestation. Mycotoxins are poisonous metabolites produced by certain fungal genera, which can infect crops both in the field and in storage. Conditions favouring the development of mycotoxins in cereals before and after harvesting are not well-understood, but are of particular importance (Jayas and White, 2003).

GRAIN STORAGE BY FARMERS

Storage of food grains initially started with farmers. The seasonal production of food grains and their relatively long shelf life encouraged the farmers to devise ways and means to hold them for longer durations; for consumption and sowing. Around 60–70% of the food grains produced in India is retained by the farming families. The maximum storage capacities for cereal grains by farmers have been observed to be up to 1.5–2.0 tonnes. The storage capacity for pulses and oilseeds is much smaller (100–500 kg).

Indigenous storage structures/methods

The indigenous storage structures differing in design, shape, size and functions have been made from a variety of locally available materials. The materials used include paddy straw, wheat straw, wood, bamboo, reeds, mud, bricks, cowdung etc. Grains could be stored indoors, outdoor or at underground level (Nagnur et al., 2006).

Indoor storage involved grain containment in structures like *kanaja*, *kothi*, *sanduka* and earthern pots. *Kanaja* is a grain storage container made out of bamboo. The base is usually round and has a wide opening at the top. The height varies. The *kanaja* is plastered with mud and cowdung mixture to prevent spillage and pilferage of grains. The top is also plastered with mud and cowdung mixture or covered with paddy straw or gunny bags.

Wooden boxes, also called as *sanduka*, are used for storing pulses, seeds and smaller quantities of grains. These boxes have a storage capacity of 300–1200 kg. In some cases, partition is also made inside the box to store two to three types of grains. A big lid on the top with a small opening enables taking out the grains. To protect the grains from moisture, the box is kept 30.5 cm above the ground level with the help of stands/legs. The box has to be regularly polished for its maintenance. *Kothi* is used to store paddy and sorghum [*Sorghum bicolor* (L.) Moench]. A room is constructed with a large door for pouring grains. A small outlet is made for taking out the grains. Earthen pots are indoor storage containers for storing small quantity of grains. These are made locally using burnt clay and are of different shapes and sizes. The earthen pots are placed at the floor level. They are arranged one above the other and known as *dokal* (Nagnur et al., 2006).

Outdoor storage of grains is done in structures made of bamboo or straw mixed with mud. Bamboo structures are used for storing unthreshed and threshed paddy. *Gummi* is an outdoor structure used for storing grains. This structure is made with bamboo strips or locally available reeds. It is usually circular or hexagonal in shape and plastered with mud. The base on which the structure is constructed is also made up of reeds or in some cases with stone slabs. The roof of the structure is usually made from loose straw. The structure is placed on a raised platform.

Bamboo structures made on a raised timber or stone platform protect grain from rat damage and prevent moisture absorption from the ground. *Kacheri* is a traditional storage structure using paddy or wheat straw, woven as rope. It is made from either paddy straw alone or paddy straw mixed with mud (Nagnur et al., 2006)

Improvements in indigenous storage structures

The indigenous storage structures although cost effective, suffer from many flaws. These are unsuitable for storing grains for very long periods. Regular mud plastering is required for a variety of indoor and outdoor storage containers and structures for increasing their life span and ensuring safe storage of grains.

The PAU bin, developed by the Punjab Agricultural University, is made of galvanized metal sheets. The bin has moderate capacities varying from 150 to 1500 kg. Pusa bin is made of mud and bricks with a low density polyethylene (LDPE) film embedded within the walls like a sandwich. The bin has minimal moisture migration during storage because of the barrier properties of LDPE. The coal-tar drum bin (200 kg) was developed at the ICAR Central Institute of Agricultural Engineering (CIAE), Bhopal, Madhya Pradesh, India, for domestic use. The domestic Hapur *tekka* or bin has capacity 200 to 1000 kg. It is cylindrical, made of galvanized iron and/or aluminium sheet, has a small hole in the bottom through which grain can be removed (Dhaliwal and Singh, 2010; Said and Pradhan, 2014).

COMMERCIAL GRAIN STORAGE

The surplus of wheat and rice is procured by the Government and its agencies every year. Of late, private sector has also started procuring large quantities of food grains for domestic and international markets.

Covered storage

The most popular storage system in India followed by the FCI, Central and State Warehousing Corporations (CWC and SWC) is bag (jute bags) storage in warehouses. The grain is packed in jute bags and stacked inside covered structures called warehouses / godowns. The godowns are conventional masonry structures constructed on a raised platform as per approved design and specifications of the Bureau of Indian Standards. The recommended capacities and dimensions of storage structures are given in Table 1. The capacities have been estimated on the basis of 22-bag high stacks.

Table 1 Capacities and dimensions of bagged storage structures

Type of godown	Capacity (tonnes)	Internal dimensions (m)	
		Length	Breadth
Small	1000	35.5	18
	2500	97.19	14.48
Large	5000	129.74	21.34

New trends in covered storage

With the advent of technology, some changes in the design of godowns have been adopted by various agencies. These changes pertain to the roofing material. The roofing material introduced is 55% Aluminium-Zinc alloy coated sheet steel (better known as GALVALUME). The steel sheet, 914 mm wide (tolerance ± 2mm), having minimum thickness 1 mm (± 0.02 mm), minimum yield strength of 350 MPa, alloy coated (55% Aluminium, 43.5% Zinc and 1.5% Silicon) on both sides is recommended for roofing. The final roof is in the form of arch and no support (truss) is required. The roof is directly mounted on the longitudinal walls.

Cover and plinth storage

Cover and plinth (CAP) storage is used for short term temporary storage of wheat and paddy in the procurement areas. During procurement operations, the storage of food grains is resorted in CAP storage, till the grains are evacuated and transported to the consuming areas.

This is an improvized arrangement for storing food grains in the open, generally on a raised plinth (0.6 m from ground) which is damp and rat-proof. The grain bags are stacked in a standard size on wooden dunnage. The stacks are covered with 250 micron LDPE sheets from the top and all four sides. Food grains such as wheat, maize (*Zea mays* L.), gram (*Cicer arietinum* L.), paddy and sorghum are generally stored in CAP storage for 3–6 months periods. It is the most economical storage structure and is being widely used by the FCI for bagged grains.

Quality control during storage of food grains

The following steps have been recommended to avoid damage to food grains in covered storage structures and CAP storage. These are practiced to avoid post-harvest losses of food grains:

- Covered storage structures may be constructed as per approved specifications.
- Adopt scientific code of practices for storage of food grains.

- Adequate dunnage materials, such as wooden crates, bamboo mats, polythene sheets may be used to check the migration of moisture from the floor.
- Fumigation covers, nylon ropes, nets and insecticides for control of stored grain insect pests may be provided in all the godowns.
- Prophylactic (spraying of insecticides) and curative treatments (fumigation) may be carried out regularly and timely for the control of stored grain insect pests. The prophylactic treatment involves the use of pesticides like malathion (50% EC), DDVP (76% EC) and deltamethrin (2.5% WP). Curative treatment involves use of fumigants to control infested stock or godown in airtight condition.
- Effective rat control measures, both in covered godowns as well as in CAP storage may be used.
- Food grains in CAP storage may be stored on elevated plinths and wooden crates used as dunnage material. Stacks are properly covered with specifically fabricated low-density black polythene water-proof covers and tied with nylon ropes/ nets.
- Regular periodic inspections of the stocks/ godowns may be undertaken by qualified and trained staff.
- The principle of First in First Out (FIFO) may be followed to the extent possible, so as to avoid longer storage of food grains in godowns.
- Only covered wagons may be used for movement of food grains, so as to avoid damages during transit.

BULK STORAGE

The agro-processing industries are more inclined in favour of bulk storage structures for food grains, as the operations such as loading/unloading, fumigation and aeration of grain bulk can be mechanized. The cost of construction and storage also favours bulk storage in silos. The agro-processing industries such as rice mills, oil milling units, roller flour mills store grain to meet their processing requirements. The requirement of storage by majority of such units ranges from 1,000 – 20,000 tonnes. There are two types of silos on the basis of design: hopper bottom silos and flat bottom silos. The capacity of hopper bottom silos range from 10 to 1,500 tonnes, whereas flat bottom silos are made to store up to 15,000 tonnes of grain. The galvanized iron corrugated (GIC) silos are quite popular in India among industries. The comparison of cost for new permanent storage facilities, using different storage types for long-term storage of grain is provided in Table 2.

Table 2 Comparison of cost for new permanent storage facilities, using different storage types for long- term storage of grain (Cost US $ per tonne of wheat)

Cost	With bag handling		With bulk handling	
	Standard warehouse	Permanent plinths	Concrete silos	Steel silos
		Fixed cost		
Capital cost	8.6	1.3	11.5	6.8
Maintenance	1.0	0.1	2.4	1.8
		Variable cost		
Material cost	0.9	1.3	0.2	0.2
Fuel/power	-	-	0.1	0.1
Labour	0.8	0.8	0.2	0.2
Bags	1.0	1.0	-	-
Losses	0.4	0.4	-	-
Total	12.7	4.9	14.4	9.1

Source: Coulter (1991)

Table 3 Comparison of grain storage systems

Considerations	Godown storage	Silos	Steel /Al domes	Circular stores
Space requirement	High	Low	High	Medium
Demand/difficulty for engineering	Low	Medium	High	High
Demand/difficulty for manufacturing	Low	High	High	Medium
Costs for charge/discharge	High	Low	High	Medium

It is evident from the calculations that the steel silos outperform other permanent structures, namely warehouse or concrete silo. The other considerations such as space requirement, difficulty for engineering, and difficulty for manufacturing and cost for charging and discharging are also important for an entrepreneur before deciding the kind of storage system. These are presented in Table 3 for four kinds of storage structures. As mentioned in Table 3 the design and manufacturing of silos is critical.

Bulk storage system in procurement sites—Silo bag technique

Bulk storage of food grains at procurement sites in large plastic bags (60 m long and 3 m diameter), having a capacity of around 200 tonnes, each have been tried in few locations for short term storage of food grains. The bags are made of HDPE. Grain is protected from rain, UV rays, atmospheric humidity and dust etc. The bags are hermetically sealed and it is estimated that the carbon dioxide level reaches around 16% within three to four weeks and is detrimental to the growth and proliferation of insects in the grain. The use of these bags can create storage capacity in shortest time and seems to be appropriate for handling bumper harvests.

PREVENTIVE TREATMENTS FOR GRAIN STORAGE

A number of preventive treatments have been tried to enhance the storage life of food grains. These include non-chemical methods such as grain drying, heat treatment, grain chilling, physical exclusion etc. Heat treatment of food grain at 55°C for 30 min can reduce the grain infestation significantly (Seidu et al., 2010).

Towne (2001) suggested various methods of sealing bins to enable reduction in the amount of fumigant used to control insect infestation. It is required to look into the fumigation and aeration needs during design and erection of storage structures. The improvements in existing structures can also be made provided the expense will be viable.

Lopes et al. (2006) developed software called AERO for simulating the aeration process in stored grain, with hot spots, using time variant ambient data.

Rulon et al. (1999) compared the economics of grain chilling, against traditional pest control methods, such as phosphine fumigation. The model considered 34 factors including electrical power consumption, capital investment cost, chemical costs, and less quantifiable factors such as worker safety, environmental issues, and changes in end-product value. When applied to the storage of popcorn, a high value specialty crop, and wheat, the annual operating costs of chilled aeration compared to phosphine fumigation with ambient aeration were up to 128 and 300% lower respectively. The effect of high capital investment with low variable costs, as with chilled aeration, was compared to the low capital investment and high variable costs of phosphine fumigation using a multi-year Net Present Cost (NPC) model.

Khatchatourian and Binelo (2008) developed a mathematical model and software for the three-dimensional simulation of airflow through high capacity grain storage bins by considering the non-uniformity of the seed mass.

Thorpe (1998) described the modelling and potential applications of a simple solar regenerated grain cooling device using desiccants. The ambient air is dehumidified and used for cooling of grain. The desiccant is regenerated using solar energy.

Scientific studies conducted at the University of Agricultural Sciences, Bengaluru, Karnataka, indicated that applying a 3 cm thick layer of sand on top of pulses stored in metal/ plastic bins; earthen pots, brick cement structures resulted in disruption of reproductive behaviour of bruchids (Prabhu, 2007).

Detection of insect activity and removal of insects from stored grains by various devices has been reported by Mohan and Rajesh (2016). Wandering behaviour of many stored-product insects helped in their detection by devices such as TNAU-probe trap, TNAU-pitfall trap and TNAU-stack probe trap (warehouse trap). The TNAU-automatic insect removal bin has been found to be very suitable for storage of paddy. TNAU UV-Light Trap is being used by organized food grain storage agencies to detect and control the insects.

GOVERNMENT'S INITIATIVE FOR AUGMENTING GRAIN STORAGE CAPACITY

National policy

The Government of India announced the National Policy on Handling and Storage of Food Grains in June 2000, to reduce storage and transit losses at farm and commercial level, and to modernize the system of handling, storage and transportation of food grains in India.

Scheme for construction of godowns for FCI through private entrepreneurs

In order to augment the storage capacity for storage of food grain stocks under Central Pool, the Government of India had formulated a scheme for construction of godowns through Private Entrepreneurs with Guaranteed utilization by the FCI for ten years.

Gramin Bhandaran Yojana

Under the *Gramin Bhandaran Yojana,* subsidy is provided for construction/ renovation of rural godowns, so as to create scientific storage capacity with allied facilities in rural areas to meet the requirements of farmers for storing farm produce.

The Warehousing (Development & Regulation) Act, 2007

The Warehousing (Development and Regulation) Act, 2007 made the Warehousing Receipt a negotiable one. The Act came into operation in October 2010. The Act envisages the registration of quality warehouses with the authority, to issue Negotiable Warehousing Receipts (NWRs). The NWRs issued by accredited warehouses having required quality infrastructure, trained personnel and registered with the WDR Authority will make the financing easier. The main objectives of the Warehousing (Development and Regulation) Act, 2007 were to make provision for the development and regulation of warehouses, negotiability of warehousing receipts, establishment of a Warehousing Development and Regulatory Authority (WDRA) and related matters (Pattanaik and Tripathi, 2016)

CONCLUSION

Safe and economical storage of food grains is essential for food security. The capacity of permanent storage structures is being augmented through various government schemes, but the pace is slow. Sanitation of structures, cleaning and drying of grains before storage, frequent monitoring of grain, aeration and fumigation are some of the strategies which need to be strictly implemented in organized and un-organized sector. It is required to put in place infrastructure required for preventive treatments (cleaning, drying, fumigation, aeration, heat treatment, grain chilling, irradiation, infrared radiation, use of ozone or nitrogen etc.) to reduce the post-harvest losses and extend storage life of grains. At present very little attention is being paid to preventive measures. Research and Development efforts are required in the areas of impact of biotic and abiotic factors during storage, detection and monitoring of spoilage, safe fumigants, uniform fumigation etc.

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