Underground and Earth Sheltered Food Storage: Historical, Geographic, and Economic Considerations

Florence V. Dunkel

Storage structures now used for bulk grain and beans have been derived from a combination of scientific experiments and tradition. Recent generations of U.S. farmers have grown up with the understanding that grain is best stored in round metal bins or wooden cribs aboveground. It is generally thought that natural wind movements in the crib structures and forced air flow from aeration fans provide the cooling and beans safely—i.e., free of moisture accumulation and the resultant insect and fungus growth, and protected from germin- ation, all of which decalcitate the commodity. Northern American farmers further believe that the low temperature of northern winters combined with the use of acetic acid will keep the grain dry or beans safe (less than 14% moisture content) for years of storage.

The technology associated with abo- aboveground metal bins evolved in the U.S. Efficient extension services at land grant institutions in the U.S. provided the mechanical and dissemination of informa- tion about storage and, subsequently, to implement modifications of storage practices. The use of round metal bins (which has apertures in the wall for natural aeration and the use of the structure to store),解决了Numerous scientific experi- ments indicate that, while these bins do maintain grain and beans providing a long-term storage, their cost is now a se- rious consideration for U.S. farmers. These bins have not only initial costs or capital investments in new structures or major modifications of existing struc- tures, but also recurrent energy costs, costs of repeatedly applying pest manage- ment chemicals, and costs associated with loss of detected quality during the grading process when the price of the grain is determined.

Traditional form of grain and bean storage in other parts of the world have evolved differently. With the exception of North America, the people of every continent in the world have developed underground storage structures for long-term storage of food. Following is a review of the varieties of underground structures that have evolved throughout the world, and research related to underground stor- age of grain and beans.

Underground Grain Storage in China

In ancient China the national grain re- serves were stored in a labyrinth of un- derground pits beneath the capital city. The storerooms were located and 16 of which have been dug out. One of the excavated stored grain. In the pit were 25,000,000 kg of millet, of which 57.2% was still recognizable material such as hulls and individual grains. This pit (pitho #25) is 7 m deep, 15.5 m in diameter at the top, and 10.5 m in diameter at the base. The largest pit excavated thus far; larger pits have yet to be excavated. The smallest pit excavated to date is 6.7 m deep, 8.4 m in diameter at the top, and 3.4 m in diameter at the base.

In preparing the pits, the burning soil provided a dry, hard layer around the silo and on the wall of the silo itself. The walls and floor were first covered with an asphalt material for waterproofing. Next the walls and floors were lined with a waterproof material. The floor was covered with wooden planks (20 mm x 30 mm thick) and nailed rice hucks. The grain was placed on top of the hucks. Layers of straw and matting on top of the grain provided a means of aver- sing moisture that might seep directly into the stored grain from the top. Soil was placed over the matting. Millet was gen- erally stored under these conditions for nine years, and other grains for six to seven years.

The Chinese understood that the cool, humid environment was an impor- tant advantage of this facility. Other advantages included pro- tective from fire and pilferage by hu- mans, birds, insects, and rodents. In addition, the underground location of these reserves was a serious matter of na- tional defense in case of invasion, destruction of the food supply is a sure way to bring a nation to the point of surrender. In Proctor-Day China is also utilizing the benefits of underground storage of grain for many reasons. One reason in quality, the storage space has been bee- hive-shaped with a narrow neck (3.5 x 5.0 m high, 2.4 m in diameter). The orifice is closed with a flat stone and a layer of soil. This cover is often made larger than the pit to form both a roof and a drainage path. The pits may be placed under the floor in farmers' houses, built on elevated land, or excavated from rock. Large pits in- clude soughum stalks and mud plaster. Insect infestation is reported as negli- gible.

There are also reports of underground wheat stores in the Turkoman Region of northeastern Iran, near the U.S.S.R.

Underground Pit Storage in Africa

Like China and the Middle East, Af- rican nations have used pit storage for bulk grain for centuries. In Kenya, pit stor- age has been used in Africa for at least 3,000-4,000 years with little change in construction methods. The excavation re- semble a ditch and is lined with layers of straw or bamboo basket work. The grain itself is covered with an inert ma- terial such as sand. These designs are de- signed to provide enough grain for a sin- gle family (approximately 3 T). In northern Egypt, a slight modification of this technique is used for storage of grain. The maximum storage period for an individual crop is 12 months. Beans and rice are under these conditions maintain good quality with insect infestation minimal and total losses never exceeding 1%.

In Morocco, most of the grain produced (wheat, barley and oats) is stored in un- derground structures. Most of these struc- tures are flash-shaped pits that are first lined with a clay that is fired and is thought to be used inside these pits for water- proofing. In India a similar type of storage pit construction was used from the 1600s to 1960s. These pits were also lined with a waterproofing coat of red-brown glassed clay. An unusual feature of these structures was the drainage system directed beneath a compacted earth layer over a perforated stone floor. These storage pits ranged from 50 T to 500 T. Research has been conducted to evaluate various lining procedures (Hinde and Daubney 1960).

In Ethiopia, underground storage pits were used in the 1980s for bulk storage. These storage structures were not often the dominant form of storage structure. Surveys indicate that approximately 62% of the farmers use pile storage. While most farmers store up to 25 T per pit, and traders store up to 100 T per pit. In coastal areas, farmers experience fluctu- ating yields, which means that pits sometimes cannot be filled to capacity with grain. The grain is stored until the grain is low, the grain is stored on load on the cob and covered to create bulk. Beans as well as wheat, barley, and tamarind are stored in these pits. Pits tend to be built near homes or in the fields, and are not associated with the field where the crops are grown. Stor- age periods usually are a few years, but sometimes are more than two years.

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pit storage is simple and involves large, deep pits covered with a mound of soil. However, it is only feasible in areas with suitable soil and climate conditions.

In tropical regions, where rainfall is abundant, earthen pits are often used for storage. These pits are dug into the ground and lined with a waterproof lining. The clay soil lining helps to prevent moisture loss, and the pits are then filled with grain.

In areas with limited water resources, concrete silos or metal granaries are often used for storage. These structures are more durable and provide better protection against pests and moisture.

In some areas, modern technology is used for storage. For example, in the United States, grain is often stored in large, climate-controlled silos to ensure that it remains fresh and free from pests.

In conclusion, the choice of storage method depends on the local conditions and availability of resources. However, all methods aim to provide a safe and reliable way to store grain until it is ready for use.

References:


O<sub>2</sub>/high CO<sub>2</sub> atmosphere is achieved by plastic-lined pits rather than by the more traditional straw-lined construction (Asanga and Mills 1985).

Conclusions

This world summary indicates that, historically, there have been two strong predictors for the geographical distribution of underground bulk grain and bean storage structures: (1) Well-drained soils or sandy soils, or (2) The existence of lime Stone formations coupled with a productive agricultural area. Why underground feed and grain storage?

Underground bulk storage structures have evolved and removed independently in many locations. With regard to underground storage of grain and other food products, the key question facing both developing and developed countries today is: What must the new generation of underground bulk grain storage structures provide for the world market? First, they must work. And they must be cost effective. There are four critical management advantages and critical physical conditions that the underground environment provides for bulk grain and bean storage:

1. A reduction in the temperature differential of the grain mass and the ambient air.
2. An environment that produces low concentrations of O<sub>2</sub> and high concentrations of CO<sub>2</sub>—a condition that confers control of insect and fungal populations.
3. Decreased possibility of bird and mammal pilferage.
4. Reduced construction costs.

All of these benefits considered together result in a net savings to the owner of the grain or beans. Let us examine in detail the first two advantages, which are the most complex and dramatic.

Temperature differential. Grain and beans are good insulators. Their kernel temperature and that of the grain mass rises very slowly. In temperate zones, as the outside temperature cool in fall, the grains also cool but not nearly as fast as the outside temperature. The grain temperature drop may lag 10°F to 20°F behind the decline in air temperature. When a 20°F or greater differential is created, heat is transferred. Moisture migration follows and moisture can accumulate, enabling insects to complete their life cycle faster and allowing fungi and the grain itself to germinate. Some insects also are attracted to certain fungi and eat the fungi. The insects grow and reproduce even faster when some fungi are more available. In the underground environment, grain and beans placed in the structure at harvest temperatures of 50°F are exposed to 70°F temperatures throughout their storage life, with little or no fluctuation. With forced aeration, of course, a grain temperature of 50°F can be maintained throughout the year in aboveground bins. Underground construction simply takes the guesswork out of the aeration timing. In situations where electricity and aerating equipment are not available or are very expensive, underground construction is a solution to the temperature differential problem during storage.

Controlled atmosphere. A similar end result accrues from the second main advantage. In a structure built in soil, air flow is minimal. With a polyethylene liner to hold grain, nearly airtight conditions can be created. When air exchange is cut off, respiratory activities of the insects, fungi, and the grain itself use up the available O<sub>2</sub>, and CO<sub>2</sub> accumulates. As CO<sub>2</sub> accumulates, insect and fungal development slow and finally cease.

Thus, underground storage is associated with two factors that lower insect and fungal development: (1) A decrease in insect and fungal development (which in turn results in reduced monetary losses when grain is graded); and (2) A drop in the need for fumigants, residual insecticides, and fungicides. These factors combined can mean additional money savings, both in initial capital expenditures and in recurrent costs. A decrease in insect and fungal development means there is less need for field drying of the grain. A reduced need for field drying, in multiple cropping systems, results in reduced crop pressure, which, in turn, may reduce the storage losses in the crop stored underground and increase yields in the next crop. A reduced need for artificial drying—particularly high-temperature drying—after harvesting results in energy savings and can also reduce stress cracking and frieness. The latter will, in turn, result in fewer places where insects and fungi prefer to develop. Figure 3 describes these interrelated factors and benefits in the form of a flow-chart.

References


