Silo bags as a storage option

For the global food system to keep up, more food grain must be produced and less must be lost post-harvest and wasted before consumption. Hermetic storage is an ancient technology used to control insect infestation in grain and preserve its nutrient quality and caloric value.

In ancient times, agricultural societies stored their surplus grain in containers or structures that kept it safe from the elements and restricted the entry of rodents, birds and insects. Well-sealed structures also prevent air exchange between the inside and outside of the storage space. By preventing air ingress to the grain, the aerobic respiration of grain, and, if present, insects and fungi, decreases O_2 and increases CO_2 in the interstitial space within the grain mass, creating a biomodified atmosphere. It has been shown that CO_2 generated from aerobic respiration alone does not increase to levels high enough to kill insects; instead, it is the lower O_2 level that is the key factor in halting insect development.

In large-scale hermetic storage, it may take weeks or months for O_2 levels to decrease by respiration to levels lethal to stored product insects (below 4% to 5%), especially when infestation is low. As a result, practical commodity management may require supplementing biomodified hermetic storage with additional control methods such as adding CO_2 or nitrogen injection or fumigation with phosphine or sulfuryl-fluoride.

Historically, cereal grains were stored hermetically in underground pits lined with clay or in small containers such as gourds or clay pots, but today technology exists that allows large quantities of grain to be stored hermetically. Large bulk silos and warehouses for both bulk and bag storage have been sealed to a high degree, most notably in Australia.

Making large structures completely gastight is a challenging and costly undertaking. In permanent structures, allowing for a small amount of air exchange between the interior and exterior of the structure (i.e., pressure venting) is a practical necessity because of potential structural damage due to internal and external pressure fluctuations. Airtightness (i.e., hermeticity) standards have been extensively researched, and the half-life pressure decay test remains the simplest and most effective test to quantify hermeticity.

Hermetic storage has been accomplished successfully on large scales in the form of underground pits covered with flexible roofs in Cyprus and Argentina, sealed commercial silos in Australia, sealed warehouses for bulk grain in China, hermetic bunker storage in Israel, and grain bag stacks enclosed within gastight liners (cocoons) in several African countries.

Silo bags

For medium-scale grain storage, silo (or grain) bags that originally were developed for anaerobic storage of chopped forages, have been adapted for bulk grain storage, first in Argentina in the early 2000s and from there adopted into many countries around the world. Silo bags utilize a time-tested method (i.e., hermetic storage) and incorporate modern technology to provide producers and commercial grain managers with an economical, flexible and safe method to store grain, especially during times of record harvests, bumper stocks and low grain prices.

Research conducted in Argentina proves that silo bags are a viable technology for a range of crops. For the past several years nearly half of the grain (40 million to 50 million tonnes) produced in Argentina has been stored in silo bags. Silo bags are a key hermetic storage technology that reduces

post-harvest losses while providing an economic alternative for farmers to gain control over marketing their stored grain between crop harvests.

Silo bags consist of three layers of polyethylene totalling 250 microns thick. The outer layer is white to reflect solar radiation, and the inner layer is black to block sunlight. A typical silo bag is about 60 meters long, 3 meters in diameter, and can store as much as 200 tonnes of wheat, maize and soybeans, though they can be smaller by simply using less of the bag. When properly sealed, the silo bag is watertight and has a high degree of gas tightness to CO_2 and O_2.

The ground upon which a silo bag needs to be placed should be level and should not accumulate standing water during rains. It also must be free of any objects that could puncture the plastic (i.e., field stubble, sharp rocks, or branches) because even very small holes will compromise the hermetic seal, allowing air, moisture and insects to enter the grain mass. Because a high level of CO_2 and low level of O_2 are the means by which insect and fungal activity is controlled in the silo bag, holes or leaks will permit air exchange with the outside and will confound the desired internal atmosphere.

Grain is loaded and unloaded from a silo bag using special equipment that can be attached to a PTO-driven tractor. The silo bags and equipment to load and unload the grain are relatively inexpensive compared to permanent grain storage structures and the associated grain handling equipment. Loading and unloading equipment cost about $50,000, and each silo bag costs about $600. Equipment is becoming increasingly available as dealers and service suppliers pick up on the trend in countries that have adopted silo bag usage. The storage environment within a silo bag can be monitored with handheld CO_2 sensors along the length of a bag. Data with bag number, position along the bag and GPS-based location identifier is uploaded automatically via mobile phone technology for online monitoring and record-keeping.

Damp grain should not be stored in silo bags. In warm temperatures, higher moisture grain creates an interstitial equilibrium relative humidity (RH) above 65% to 70%, which provides a good environment for fungi to develop. While it has been shown that low oxygen environments can prevent the proliferation of certain species of fungi present in grain, trials in Argentina with damp grain stored in silo bags showed that fungi develop to the detriment of grain quality. It is therefore best to store grain at the recommended safe storage moisture content when placed into silo bags. Safe storage moisture content depends on weather conditions during the warmest period of storage at the geographic location of the silo bags.

Recommended best management practices

Before choosing to utilize silo bags, in addition to the economics, the following best management practices adapted from a list compiled by Purdue University Extension should be considered:

- Maize, soybeans and wheat stored in silo bags should have moisture content at or below 15%, 13% and 12%, respectively. Sunflower and canola should be stored with moisture content below 10%. It is prudent to err on the conservative side and rather store drier than wetter grain, oilseeds and pulses.
- Maize dried using a high temperature dryer should be cooled to within a few degrees of ambient temperature prior to bagging so that heat is not trapped in the bag when it is sealed. Otherwise condensation on the underside of the plastic lines could lead to fungal development and premature grain spoilage.
- Silo bags should not be over loaded; most bags only stretch by about 10% and over filling could result in the bags breaking, especially when they are unloaded. Also, sufficient lengths of plastic liner at the ends are needed to properly seal the bags as filling is started and at the end.

- Maize, soybeans and other crops should not be stored in the bags beyond the cool weather period, which for fall harvested crops in North America means no more than six months. Winter conditions in the US Midwestern and Great Plains and Canadian Prairies will keep the grain fairly cool and slow down any biological activity. During spring warm-up when snow melts, water may leak into punctured bags and as temperatures rise biological activity such as the growth of fungi and insect pests will accelerate in damp grain.
- Grain quality should be monitored regularly along each bag using CO_2 sensing technology, and bags identified with increasing CO_2 between bi-weekly readings should be designated for earlier unloading than bags with stable CO_2 readings.
- Bags with increasing CO_2 should be sampled using a grain trier to determine the extent of water ingress or spoilage that can be detected near the surface. Punctured liner locations for sampling must be resealed after sampling and can be reused. Punctures must be patched using specially provided sealants and tapes (not duct tape) available from silo bag dealers.
- Bags should be inspected frequently for damage of the liners by rodents. Note that snow cover can hide punctures and therefore snow should be cleared from the bags to effectively assess damage to the flexible liner.

Benefits of using silo bags

- Reduced capital investment required compared to building permanent steel bins; estimated at about $60 to $80 per tonne ($1.50 to $2 per bushel) of stored grain.
- Cost-effective alternative that can act as buffer storage estimating to cost $2.75 per tonne (7 cents per bushel) of grain stored.
- Simplification of harvest logistics by providing flexible storage even along the edge of the field, especially when logistics to reach permanent storage is a constraint.
- Easy means for on-farm segregation of commodities, thereby providing a suitable option for identity preservation of specialty grains.
- Maintain grain moisture content during storage when a hermetic (air-tight) environment is maintained.

Disadvantages of using silo bags

- Require special loading and unloading equipment, which first-time users will need to purchase or rent through fee-for-service providers.
- Extra labour and time are needed to load and unload, and to monitor stored grain in silo bags.
- Stored grain is more susceptible to negative influences from the environment, especially extreme weather.
- Stored grain is vulnerable to damage from vermin and insect pests, thus protective measures and monitoring need to be in place.
- Under US warehouse licensing rules, silo bags are considered temporary storage and thus typically cannot be used for warehouse receipt of grain. Users should also check with their crop insurance agent regarding insurance coverage.
- Stored grain cannot be aerated to control moisture movement, temperature changes, and fungi and insect development through cooling.
- Silo bags can only be used once as they are cut open along the top during retrieval of grain. Used bag plastic needs to be disposed of properly, ideally by recycling.