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Hermetic Storage of Food Grains

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The technology of hermetic storage can revolutionize food grain storage practices in several under-developed and developed countries. Products such as cereal grains (rice, corn, barley and wheat), cocoa and coffee have been stored in hermetic units for extended duration.

Introduction

Food grain storage is a complex man-made ecosystem. The quality of stored grain is affected by several biotic and abiotic factors (Jayas, 1994). Several technologies have been developed for safe, long/short term storage of food grains. One such method is the storage of food grains under hermetic conditions. The concept of hermetically storing food grains dates back to several centuries ago. Food has been stored in under-ground pits made of soil/rock. In such cases, 100% air-tightness could not be ensured because of gas exchange through walls/roofing. Further, the risk of high carbon-di-oxide levels has been an important concern in underground pits; because of suffocation and other occupational hazards during unloading operations. Grain has also been stored in semi-underground hermetic pits in Argentina. This was made possible with concrete line trenches with flexible roofs. Apart from these, even at domestic level, hermetic units have been prepared using locally available materials and stored above ground level (Navarro *et al*., 1994). The technology of hermetic storage can revolutionize food grain storage practices in several under-developed and developed countries. Products such as cereal grains (rice, corn, barley and wheat), cocoa and coffee have been stored in hermetic units (Jonfia-Essien *et al*., 2010) for extended duration.

Principle of Hermetic Storage

Insects require oxygen for respiration. In the course of respiration, oxygen levels in the grain bulk decrease (when sealed hermetically). This goes in hand with increasing carbon-di-oxide levels. In fact, the effect of oxygen depletion is more significant that carbon-di-oxide accumulation (Edwards, 1953; Bailey, 1965). In the course, insects cease to feed, grow and reproduce. Disruption in the respiratory process result in decline in respiratory quotient values (the ratio of carbon-di-oxide evolved to the ratio of oxygen consumed) as oxygen levels decrease with time. Consequently, populations remain small, inactive and eventually die (of desiccation or asphyxiation). Additionally, hermetic storage impedes fungal growth (Quezada *et al*., 2006; Murdock *et al*., 2012).

Air-tightness can be created using one or more of the following methods: (1) organic hermetic storage: a modified atmospheric approach in which the metabolic activity of insects/fungus itself result in lowering oxygen levels in the grain bulk; (2) vacuum hermetic storage: in which low pressure created in the system results in automatic disinfestations of grain (this technique is applicable only for non-crushable commodities); and (3) gas hermetic storage: in which an external gas (such as carbon-di-oxide) is used to create a controlled atmosphere system (Chakraborty and Alice, 2014). This method can be applied for crushable commodities such as dry fruits. Based on product type, requirements and inventory, different designs can be adopted for specific applications.

Examples of Commercialized Units

Not all experimental hermetic storage units have shown successful results. This section lists some of the most successful commercialized units, particularly for developing and under-developed countries.

1. Purdue's Triple Bags^{TM} – involves the use of a triple-bag system into which grain is filled. The two inner liners are HDPE based and an outer sack of woven polypropylene is used. Though excellent storage life was observed, capacity of this unit is less. (Jones *et al*., 2011).
2. GrainPro's Cocoons^{TM} – using which storage can be done at farmer cooperative/ small trader level. The unit capacity ranges from 10-1000 tonnes. In practice it is an enclosure for stacks of grain storage inside and sealed with a zipper. The material used is usually a 0.83 mm thick PVC. Oxygen permeability and water vapour permeability values are in the range of 400 cc m^{-2} day^{-1} and 8 g^{-2} day^{-1}, respectively.
3. GrainPro's SuperGrainBags^{TM} – are small-scale storage units which can be moved from one place to another, at ease. Their storage capacities range from 60 kg to 2 tonnes. By design, it is a three-layered coextruded plastic with thickness of 0.078 mm. Oxygen permeability and water vapour permeability values are in the range of 3 cc m^{-2} day^{-1} and 8 g^{-2} day^{-1}, respectively.
4. GrainPro's TransSafeliners^{TM} – are designed to protect bagged commodities during shipping. Standard sizes are 20 and 40 foot. These units can have ultralow permeability and are made of the same material as SuperGrainBags. An added advantage of this technology is that the risk of condensation can be eliminated (Villers *et al*., 2008).
5. Postcosecha Galvanized Steel Silos – are built locally using simple tools. They are made of 0.7 mm galvanized steel sheets with lead based solder. Storage capacities range from 180 to 1360 kg. A 37 cm diameter intake throat is provided for filling and inspection. To facilitate easy discharge of the product, a 15 cm diameter outlet port with 15 cm protrusion is provided (Bern *et al*., 2013).

Several other designs have been experimented by different researchers. However, the tediousness in maintaining air-tightness and providing sufficient barrier to moisture are important concerns. There are also issues in terms of scale-up. Further, polymer-based hermetic storage materials are at a risk of rodent attack and insect entry. Importantly, when stored is under high relative humidity and temperature (in hermetic conditions), there is a risk of loss of seed vigor (Weinberg, *et al*., 2008) and is associated with grain quality loss.

Management Protocols for Hermetic Storage

Even under hermetic storage, oxygen depletion and carbon-di-oxide build-up depend on the following factors: (1) air-tightness of the system, (2) types and population of insects, (3) fungal inoculums, (4) quality and type of grain, and (5) grain moisture content. Important parameters to be considered while storing grain under hermetic conditions are listed below.

1. Grain moisture must be brought down to 12-14% prior to storage (to avoid loss in germination and viability). Studies on storage of high moisture maize have shown that the grain can be used for animal feed purposes. However, in most cases, grain storage with high moisture content will result in caking problems, kernel discolouration and moulding.
2. Permeability of packaging material and the changes in its properties over time.
3. Frequency of opening the system will have significant implications on biotic and abiotic parameters of the system. Also, hermetic storages can be fumigated initially; the amount of fumigant used is reported to be $1/200^{th}$ of what is usually used in a non-hermetic store (because of the airtight nature). However, if proper management protocols are not followed, insects would develop fumigant resistance (even under hermetic conditions).
4. Headspace must be avoided as it would result in difficulties in maintaining gas compositions levels.

5. Caution must be taken to sample the grain appropriately for verifying the presence of insects. There is more change of presence of insects at regions near the surface. Further, there are higher chances of spoilage, insect infestation, free fatty acids and alcohol acidity in the top layers.

Advantages Hermetic Storage Units

Hermetic storage provides an eco-friendly method of food grain storage. As there is no requirement for chemical fumigation, there is no risk to residues. The technology is simple and effective. No detrimental effects on germination, milling and baking properties of food grains have been observed when stored in hermetic conditions. The technology is appropriate for storage of grains in tropical conditions also. Importantly, it better suits large structures. This is because as the ratio of surface area to volume of the packaging material lowers, the transfer rates of oxygen across the polymer also lower. Generally large hermetic units have been reported to cost around Rs. 3000 to 6000 per tonne of grain (assuming a life of around 10 years). Hermetic storage systems have also been suggested alternatives for improved food grain storage under changing climatic conditions (Moses *et al.*, 2015).

Conclusion

Hermetic storage best suits large-scale and long-term projects. There is a need for research: to develop affordable and reliable instrumentation (for gas composition analysis), to understand the effect of hermetic storage on different life stages of insects, to develop a hermetic seed storage supply chain, to develop on-farm hermetic storage structures for India, to explore the scope of storing pulses in the tropics and to develop novel packaging materials that offer improved mechanical strength and better gas and water vapour barrier properties.

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