New Applications of Hermetic Storage for Grain Storage and Transport

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Abstract

Recent evolution of pesticide-free post harvest hermetic storage for dry commodities as now used in 38 countries is described, and its current application in the storage of grain and other commodities is discussed and illustrated. Results of studies carried out on the protection of seeds, rice, maize, wheat, pulses, cocoa and coffee are presented. Plastic structures suitable for long-term storage systems have been developed and applied. The growing number of types of flexible hermetic containers for various needs, especially in tropical conditions, is documented. Types of hermetic containers include: 1) Portable containers of 60-kg to 2-tonne, called SuperGrainbags™ which are suitable for seed storage in bulk; 2) Bulk storage for household or farm use and daily withdrawal of grain of 1-tonne called Grainsafe II™; 3) Flexible enclosures of 5- to 1000-tonne capacity termed storage cubes or Cocoons™, designed for storage at the farmer-cooperative and small trader level or larger commercial and strategic storage facilities; 4) Hermetic Bunker storage for long-term storage in bulk of 10,000- to 20,000-tonnes; 5) TranSafeliner™ provide quality preservation, insect control, and prevention of condensation during shipment of bagged commodities in containers across intercontinental distances. Recent applications for wheat storage in bunkers in Jordan, and cocoa storage in West Africa, and the growing use of hermetic liners for intercontinental shipments of a variety of commodities, are described. Key performance parameters for safe storage in the face of elevated humidity and temperature in preventing growth of molds and the survival of insects for dry and wet commodities are discussed. Economic analysis is provided for representative applications, including rice, maize and cocoa.

Keywords: Hermetic storage, Modified atmospheres, Quality preservation, Storage insect control, Flexible storage structures,

1. Introduction

A new approach to cocoa bean storage, “hermetic storage” (HS), has been investigated in both laboratory and field studies to protect them in storage and in transit, and is now in commercial use in Africa, Asia and Latin America. Hermetic storage is a type of modified atmosphere (MA) that has now been applied for the protection of stored agricultural commodities including cocoa beans as well as coffee, rice, maize, pulses and seeds (Navarro et al., 1984; 1993; Navarro, 2006). It is also called "sealed storage” or “air-tight storage” or “sacrificial sealed storage” or “hermetic silo storage”. This method takes advantage of sufficiently sealed structures that enable insects and other aerobic organisms in the commodity or the commodity itself to generate the MA by reducing the O_2 and increasing the CO_2 concentrations through respiratory metabolism. It has been shown that hermetic storage allows safe storage for periods ranging from weeks to many months, as well as during shipment across intercontinental distances with storage losses typically well below 1%.

Fumigants are still widely used for pest control in stored products, but non-chemical and environmentally user-friendly methods of pest control in the post harvest sector are becoming increasingly important. Methyl bromide (MB) will be phased out in developing countries by 2015, because of its contribution to stratospheric ozone depletion (UNEP, 2002). In contrast; phosphine remains popular, particularly in developing countries, because it is easier to apply than MB. However, some insects have developed resistance to phosphine in some countries over the last decade (Savvidou et al., 2003).

Storage problems prevail in the presence of adequate oxygen and temperature. In the presence of high relative humidity molds develop to cause quality deterioration resulting in an increase in free fatty acids (FFAs), rancidity and mycotoxins. These postharvest problems are eliminated through the lethal effect of a low O_2 and high CO_2 atmosphere produced through respiration processes of biological agents. Under hermetic conditions, stored commodities with intermediate moisture contents generate modified atmospheres due to the respiration of the microflora and the commodity itself. The objective of this paper is to provide data on the novel approach of using hermetic storage based solely on biogenerated MA as an insect control, and quality preservation method for stored cocoa beans, coffee, seeds and other stored agricultural products.

2. Storage structures and enclosures developed for hermetic storage

Modern HS systems use special low permeability flexible plastic enclosures. These hermetic storage containers have evolved to store a variety of dry commodities in the range of 60 kg to 20.000 tonnes. They became commercially available starting in the early 1990's, and today are in use in more than 38 countries in a variety of configurations.

A few specialized applications require rapid disinfestation, such as in 3 days for dried figs (Ferizli and Emekci, 2000). In these, oxygen levels are reduced rapidly, either by purging with CO_2 (Gas - Hermetic Fumigation "G-HF"), or by applying a significantly high vacuum (Vacuum - Hermetic Fumigation "V-HF"). In either case, the process can quickly reduce oxygen content to below 1% to 2% (Navarro et al., 2002; Villers et al., 2008).

The most widely used form of HS is the Cocoon™ (Fig. 1A). It is manufactured in capacities ranging from 5 tonnes to 300 tonnes. Cocoons are made from specially formulated flexible 0.83 mm thick PVC with permeability to oxygen of 400 cc/m^2/day and to water vapour of 8 gm/m^2/day. A newer type of Cocoon called the MegaCocoon™ has more recently been introduced for larger scale storage of up to 1050 tonnes, with initial installations in Sudan (Fig. 1B).

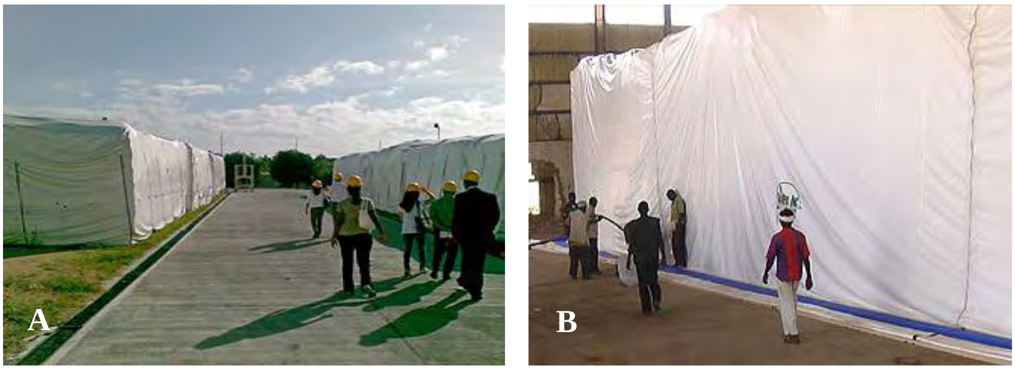

Figure 1 **A:** Corn, Outdoor storage in Cocoons™, Philippines, 2008 (left). **B:** 1050 Tonne MegaCocoon™, 2009 (right).

For smaller unit containers of 60 kg to 90 kg capacity, a transportable SuperGrainbag™ (SGB) is used (Fig. 2A). The SGB is a 3-layer coextruded plastic with thickness of 0.078 mm, 3 cc/m^2/day permeability levels for oxygen and for water vapour of 8 g/m^2/day. Using the same material, the SuperGrainbags-HC™ has become available for use with mechanized loading, which handles up to a 2-tonne capacity for bags or bulk storage (Fig. 2B).

Figure 2 **A:** 60kg SuperGrainbag with Corn seeds. **B:** SuperGrainbag -HC™ storing paddy inside woven protective polypropylene bag.

To protect bagged or bulk commodities against damage and deterioration when shipping across intercontinental distances in 20- and 40-foot standard shipping containers the TranSafeliner™ was introduced in 2008 (GrainPro, 2008) (Fig. 3).

Figure 3 TranSafeliner™ with coffee, Guatamala

The TranSafeliner provides hermetic storage during transport in a standard shipping container using the same type of ultra low permeability co-extruded plastic used in the SuperGrainbags shown in Figure 2 (Villers et al., 2008).

3. Current applications of hermetic storage

3.1. Hermetic storage of rice and rice seeds

As a result of extensive studies at IRRI (Rickman and Aquino, 2004) and later by PhilRice (Sabio et al., 2006), over the last 10 years, the benefits of storing both rice and rice seeds in hermetic storage are now well understood and in widespread use, particularly in Asia (Villers et al., 2006). The Cocoons shown in Figure 1 are used by the National Food Authority of the Philippines, to safely store rice paddy for up to one year. Hermetic storage applications for rice and/or rice seed are currently found in such countries as: Cambodia, East Timor, Indonesia, India, Pakistan, Philippines, Sri Lanka, and Vietnam (Montemayor, 2004).

3.2. Hermetic storage of wheat and barley

Hermetic storage of wheat in “Hermetic Bunkers” with capacities ranging from 10.000 to 20.000 tonnes was first introduced in the early 1990’s, as shown in Figure 4. Hermetic storage of wheat, stored at or below its critical moisture content of 12.5%, provides storage without significant degradation of quality, including maintenance of baking qualities, for up to 2 years (Navarro et al., 1984; 1993). In Cyprus such Bunkers allowed quality preservation of barley for 3 years, with total losses of 0.66% to 0.98%, and with germination remaining above 88% (Varnava and Muskos, 1997).

Figure 4 20.000 tonnes of Wheat in Hermetic Bunker, Jordan 2009

3.3. Hermetic storage of dry maize

Cocoons are widely used in Rwanda, Ghana and the Philippines for storing both shelled and unshelled maize, in capacities ranging from 50 to 1050 tonnes (Figure 1). Similar quality preservation results were obtained for maize when stored in 60 kg capacity SuperGrainbags. The large flexible hermetic storage units are generally used at the village level, but also as strategic reserves to prevent famine at the district level (Navarro, 2006; Montemayor, 2004, Navarro et al., 1995).

3.4. Preservation of high moisture maize

Under humid and warm conditions harvested grains should be dried to safe moisture levels that inhibit the activity of microorganisms. Drying to these moisture levels is often not economical for farmers in developing countries. Laboratory studies were carried out on the effect of various moisture contents on the quality of maize grains in self-regulated modified atmospheres during hermetic storage (Weinberg et al., 2008). Shelled maize of 26% moisture content was stored in a Cocoon™ under hermetic conditions for 96 days to demonstrate the effectiveness of maintaining its quality prior to subsequent drying or processing into feeds or ethanol. The high moisture maize in the Cocoon™ initially had 59 ppb of aflatoxin, which increased to 90 ppb after one week of storage and remained at that level for 96 days (Arnold and Navarro, 2008). Feeding trials indicated that wet maize can be safely stored for extended periods of time without significant increase in aflatoxin, and without significant changes in starch.

3.5. Hermetic storage of pulses (beans)

Beans in storage are subject to invasive pests such as *Callosobruchus maculatus* (F.) and *C. chinensis* (L.), which are controlled through hermetic storage. In Rwanda and Ghana, storage of beans in Cocoons of 20 to 150 tonne capacity has permitted groups of farmers to hold their crops off the market while waiting for more favorable market prices (MINAGRI, 2006).

3.6. Hermetic storage of coffee

Field data from Costa Rica shows that preventing the penetration of external humidity alone has proved sufficient to protect coffee bean quality for up to 9-months (Aronson et al., 2005). Coffee is now stored commercially in portable SuperGrainbags, or in larger Cocoons for storage to preserve quality, and also, for long transit-time shipments in shipping containers without refrigeration, using SuperGrainbags, or TranSafeliners™. Hermetic coffee storage of green coffee beans is now practiced in Costa Rica, East Timor, Ethiopia, Jamaica, Hawaii, Peru, and the continental United States.

3.7. Preservation of stored cocoa beans

According to the Transport Information Service (TIS) (2009), moisture content higher than 8% corresponds to the rapid mold growth threshold of 75% relative humidity. It is thus recommended to insist on a water content of 6% or less when transporting cocoa beans in containers.

Data was shown for insect control and for quality preservation of stored cocoa beans by employing a novel approach through the use of biogenerated modified atmospheres as a methyl bromide alternative. The respiration rates of cocoa beans at equilibrium relative humidities of 73% at 26ºC in hermetically sealed containers depleted the oxygen concentration to <1% and increased the carbon dioxide concentration to 23% within six days. A hermetically sealed flexible structure containing 6.7 tonnes of cocoa beans at an initial moisture content of 7.3% (70% equilibrium r.h.) was monitored for oxygen concentration and quality parameters of the beans (Navarro et al., 2007). The measurements showed a decrease in oxygen concentration to 0.3% after 5.5 days (Figure 5). No insects survived the oxygen depleted biogenerated atmosphere. These encouraging results reveal the possibility of utilizing biogenerated atmospheres in integrated pest management (IPM) for quality preservation (by preventing the development of FFA, molds, and mycotoxins), and insect control of cocoa pests (Jonfia-Essien, 2008a; 2008b).

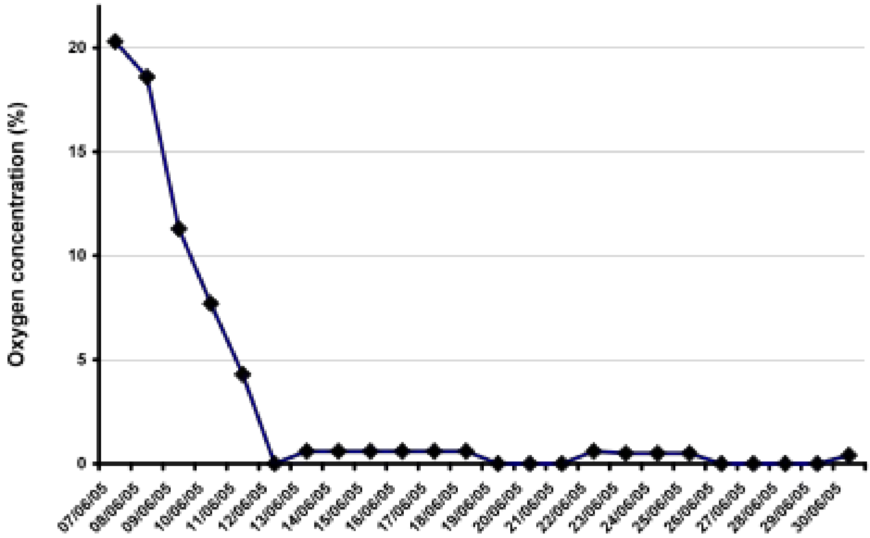

Figure 5 Changes in oxygen concentration in cocoa beans, Makassar, Indonesia, 2005

4. Other commodities

Hermetic storage is currently used for such commodities as sorghum, and rice bran. A 2009 trial (unpublished) in Kerala, India, suggests possible hermetic storage application to tea storage by maintaining constant humidity.

5. Conclusions

Hermetic storage was shown to be a successful storage method for the protection of the commodities replacing fumigants for insect control and for quality preservation of stored products. Hermetic storage is achieved in specially constructed plastic structures suitable for long-term storage systems, as well as intermediate storage of cereals, pulses, coffee and cocoa have been developed and applied. Flexibility, transportability, ease of erection, simplicity of operation and maintenance and durability are distinct advantages. Their availability in various sizes, capacities and forms can suit a wide range of requirements to fit several levels of operation.

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