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# WORLDWIDE USE OF HERMETIC STORAGE FOR THE PRESERVATION OF AGRICULTURAL PRODUCTS

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## ABSTRACT

This paper discusses various forms of hermetic storage and transport, which preserve dried commodities such as grains (rice, maize, beans, wheat), silage, coffee, cocoa and seeds. Discussed are its limitations, and the expanding needs of 5 continents and 90 countries that use hermetic storage. Hermetic storage has proven especially effective in hot, humid climates to combat frequent, devastating post harvest losses and prevent the growth of mold related aflatoxins, a major public health hazard. With hermetic storage systems, post harvest losses are reduced to < 1% in hot, humid climates; this is in marked contrast to conventional storage systems requiring pesticides or refrigeration, which often reach 25% losses or more. Scientific information based on insect and commodity respiration, as well as the use of injected $CO_2$ (in some cases) to more rapidly decrease oxygen levels, is now a superior alternative to refrigeration for multi-month seed preservation. Finally, the paper addresses the cost effectiveness of hermetic storage versus alternative storage systems.

**Key Words:** Safe Hermetic Storage, Modified Atmosphere, Long Term Storage, Cocoon™, Insect Control, Flexible Storage Structure, Hermetic Bunker™, SuperGrainbag™, TranSafeliner™, Solar Dryer, SilBag™, GrainSafe™, Collapsible Dryer Case™, GrainKeep Center™

## INTRODUCTION

The use of fully hermetic storage and the number of hermetic applications have grown rapidly since the last CAF conference in 2008 (Villers et al., 2008). Several scientific questions about the technology have been answered. The year 2012 saw the introduction of a number of new forms of hermetic storage such as the SilBag™, Collapsible Dryer Case II™ (CDC II), GrainSafe™, GrainKeep Center™ (GKC) and larger scale bulk storage. Semi-hermetic storages, such as the Purdue PICS (Purdue Improved Cowpea Storage) bag and the Argentine Silo Bag, have also been used primarily in Africa and Latin America for some applications.

### The SilBag:

The SilBag™ simplifies the process of storing high quality silage for cattle and dairies, eliminating the need for extensive compression because of its airtight environment (Fig. 1).

Fig. 1- SilBag™ for cattle farms and dairies.

**SuperGrainbag IV R™:**
The SuperGrainbag IV R is made using a significantly tougher plastic than that of previous SuperGrainbags to provide a high level of insect resistance against larger grain borers and cowpea weevils, which have been known to penetrate thin plastic membrane walls.

**GrainSafe XL™:**
The new 10 to 50 tonne capacity GrainSafe XL is a small bulk storage device for larger farms.

IMPROVEMENTS FOR SUCCESSFUL APPLICATION OF HERMETIC STORAGE

**Conditions for Implementation of Hermetic Storage:**
Hermetic storage relies primarily on the respiration of insects, microorganisms, and the commodity itself (Villers et al., 2006a; Villers et al., 2006b). Any dry commodity that has been previously fumigated to control insects, may take weeks to reduce oxygen levels without the injection of supplementary carbon dioxide. Respiration rates of insects and the time required for oxygen levels to drop sufficiently is a strong function of initial infestation and ambient temperature. Further, the time it takes to achieve low oxygen levels in hermetic storage of dry commodities increases as the temperature drops significantly below 20°C; below this temperature, respiration rates begin to drop dramatically. On the other hand, respiration rates of wet commodities are dictated by the level of moisture content.

**Supplemental Carbon Dioxide:**
In certain applications, respiration alone is too slow in reducing oxygen levels. The injection of supplemental $CO_2$ speeds up the process of reducing the $O_2$ level to critical levels of <3% for insect survival and has been shown to be especially beneficial in the storage of peanuts, where the process may otherwise take 30 days or more (Navarro et al., 2012). It has also been used for organic fig storage (Ferizli and Emekci, 2000) and for the fumigation of flowers and books.

**Oxygen Absorbers:**
The insertion of an inexpensive oxygen absorber packet into small hermetic storage systems is more practical for field applications than the injection of $CO_2$.

**Novel Scientific Data on Beneficial Use of Hermetic Storage:**
The detrimental effects of high levels of aflatoxins on public health (i.e., HIV and cancer) have been studied for some time (Williams, 2011). In 2010, 10% of the Kenyan maize crop had to be rejected because of excessive aflatoxin levels. Many countries have restricted permissible aflatoxin levels for humans to five to 10 ppb. According to the 2011 World Bank report about grain losses in East Africa, “Due to the combined effect of aflatoxins and insect infestation, losses in a number of areas are 25% [for maize]” (World Bank Report, 2011).

Recent work on peanuts, summarized in Table 1 attempt to demonstrate that aflatoxin development was prevented at low $O_2$ atmospheres developed under hermetic conditions due to the respiration of peanuts only or at high $CO_2$ atmosphere generated by purge of the $CO_2$. The lack of the presence of the toxigenic strain of microflora did not produce sufficient evidence to determine whether aflatoxin growth was inhibited. But at the same time the tested hermetic conditions or high $CO_2$ levels did not promote aflatoxin development. On the other hand, the most significant data on peanuts was obtained on prevention of FFA growth. Table 1 shows that FFA increase can be prevented under hermetic storage with a low $O_2$ or a high $CO_2$ level atmosphere (Navarro et al., 2012). In commodities such as peanuts, decrease of $O_2$ through respiration alone (in the absence of sufficient insect population and at low moisture content) may take several weeks – too long to prevent significant aflatoxin growth and oxidation. The injection of $CO_2$ or the use of an oxygen absorber appears suitable means for generating the appropriate hermetic storage atmospheres.

Dr. Silverio Garcia-Lara at Technological University de Monterey, Mexico has recently successfully tested the use of a newer, more resistant plastic membrane (0.078 mm) (now known as the SGB IV R) to prevent penetration of hermetic storage bags by cowpea weevils (*Callosoburchus maculatus*(F.)) and larger grain borers (*Prostephanus truncatus* (Horn)), which have been known to penetrate earlier hermetic and semi-hermetic bag liners.

## TECHNOLOGIES DEVELOPED FOR THE PROPER IMPLEMENTATION OF HERMETIC STORAGE

**Collapsible Dryer Case (CDC):**
Successful, long term hermetic storage requires proper drying to reduce moisture content below critical levels and prevent deterioration in storage. The availability of low cost, portable, rain protected solar dryers has greatly facilitated this drying of commodities prior to storage. During rainfall, the Collapsible Dryer Case II (CDC) with inflatable edges (Fig. 2) can be zippered shut, with one end pulled over the other.

Fig. 2- CDC III™ Collapsible Solar Dryer.

Table 1. Moisture Content (%), FFA (% oleic acid), Aflatoxin (µg/kg) values and CFU (Colony Forming Units) for molds at the beginning of the trials for the targeted 7 and 8 % moisture contents of peanuts after 90 days of storage at 30°C

| Moisture Content (%) | Tested parameters | Initial | After 90 days | | | | |
|---|---|---|---|---|---|---|---|
| | | | Hermetic sound peanuts | Hermetic with 3% broken peanuts | $CO_2$ with 3% broken peanuts | Control | Control with 3% broken peanuts |
| 7 | % Moisture Content | 5.97±0.03 | 6.80±0.20 | 7.20±0.21 | 6.60±0.40 | 6.33±0.53 | 6.60±0.26 |
| | FFA (% oleic acid) | 0.36±0.01 | 0.63±0.53 | 0.70±0.17 | 0.43±0.07 | 0.57±0.03 | 1.50±0.12 |
| | Aflatoxin (µg/kg) | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| | CFU molds | $3*10^2$ | $1.8*10^3±1.2*10^3$ | $1.7*10^3±7*10^2$ | $9.7*10^1±28$ | $1.3*10^4±9*10^3$ | $4*10^4±3*10^3$ |
| 8 | % Moisture Content | 7.53±0.07 | 6.87±0.15 | 6.37±0.2 | 7.10±0.32 | 6.63±0.19 | 7.30±0.17 |
| | FFA (% oleic acid) | 0.42±0.09 | 0.67±0.17 | 2.13±0.07 | 0.77±0.03 | 2.57±0.47 | 4.00±0.42 |
| | Aflatoxin (µg/kg) | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| | CFU molds | $3.1*10^2$ | $8.4*10^3±5*10^3$ | $6.3*10^1±18$ | $1.2*10^1±4$ | $7.6*10^5±5*10^5$ | $7.5*10^5±2*10^5$ |

(Navarro et al., 2012)

**Grainkeep Center (GKC):**
Using the "spoke and hub" concept, the GKC "brings the market to the farmer" to within a 25 km radius (Fig. 3). The first two GrainKeep Centers are public/private partnerships owned and operated by a local entrepreneur (KPMC) in Kenya. Farmers can bring bags of grain to a hermetic storage unit within their own village and when the local storage unit is full, the bags are transferred to the Center. The Center can measure aflatoxin levels and provide access to simple, modern equipment such as threshers and dryers. Because the GKC provides safe hermetic storage for large volumes, it attracts large buyers such as the World Food Program (P4P). Typically, one GrainKeep Center can service about 2,200 farmers with a capacity of 2,000 tonnes. This significantly improves family income for approximately 11,000 family members.


Fig. 3- GrainKeep Center™ - Bringing the market to the farmer.

**Guatemala:**

The World Food Program (P4P) has widely distributed more than three thousand GrainSafes™ (Fig. 4) to farmers in Guatemala in response to the demand for medium sized hermetic containers for bulk grain with continuous "in" and "out" capabilities. Also, after testing metal and rigid plastic silos that require the use of fumigants, the Guatemalan farmers found that they preferred pesticide free hermetic storage (GrainSafes™).

Fig. 4- GrainSafe™, World Food Program, Guatemala, 2011.

**Ghana:**

The Cocoa Board of Ghana uses several hundred large Cocoons™ with a capacity of up to 320 tonnes to store cocoa beans (which are highly susceptible to rancidity) prior to exporting them. More recently, they started using TranSafeliners™ in shipping containers for protection during transport for organic cocoa.

**Nepal:**

In Nepal, a large number of small farmers have started using man portable SuperGrainbags™. Fig. 5 shows a farmer storing her corn in a Coop in Mulpani village near Kathmandu, Nepal.

Fig. 5- Maize storage in Nepal.

**Afghanistan:**
The largest scale application of SuperGrainbags for small farmers was funded by USAID in Helmand Province, Afghanistan in 2010 and 2011, along with large quantities of CDC rain protected solar dryers.

**Brazil, Peru, and the Philippines:**
Large scale storage of maize and rice seeds in Cocoons is also current in Brazil, Peru and the Philippines. Studies on rice seed by the International Rice Research Institute (IRRI) and PhilRice in the Philippines show that adequately hermetic storage can preserve rice seeds for up to a year with almost the same results as in cold storage, without the energy requirements. (Villers and Gummert, 2009; Sabio et al., 2006) Elimination of insect damage, reduction of moisture fluctuation, and low oxygen/high carbon dioxide atmospheres create ideal conditions for preserving germination and vigor.

## SAFE STORAGE FOR 5 MAJOR CROPS

**Seeds:**
PhilRice and BPHRE in the Philippines have studied long term storage of hybrid rice seed extensively. They compared four methods: hermetic, cold room, air conditioning and unprotected PP bags. Table 2 shows that of the various storage technologies observed, hermetic storage was the most effective in controlling insect infestation and reducing weight loss (Sabio et al., 2009). In addition, the benefits of hermetic storage of rice seeds, and paddy over the alternative storage methods are further described by Villers and Gummert (2009).

Table 2. Mean percent germination rate of Mestizo 1 (PSB Rc72H) hybrid paddy seeds stored under different storage technologies and durations

| | Storage duration (months) | | | |
|---|---|---|---|---|
| Storage method | 0 | 3 | 6 | 9 |
| Hermetic storage | 96.16 abA* | 96.47 a A | 93.30 a A | 86.15 b B |
| Cold room | 96.80 a A | 97.57 a A | 92.95 a B | 89.60 a C |
| Air conditioned | 94.30 ab A | 94.75 ab A | 88.13 b B | 85.82 b B |
| Control | 92.87 b A | 92.92 b A | 76.38 c B | 74.70 c B |

*Means in a column followed by a common small letter are not significantly different at 5 % level of significance.
Means in a row having a common capital letter are not significantly different at 5 % level of significance.
(Sabio et al., 2006)

**Coffee:**
Farmers, traders, importers and roasters now use hermetic storage for coffee in some 20 countries (Aronson, 2005). *Coffee and Cocoa International* writes, “As coffee growers, logistics companies and roasters search for a way to protect high quality coffee during storage and transportation, one particular technique seems to be coming to the fore. Hermetic products are being used around the world to preserve the quality of coffee prior to roasting, and prevent the development of FFAs and OTA in cocoa” (Coffee and Cocoa International,

2011). Green coffee or cocoa can be economically stored and transported intercontinentally when hermetically protected with TranSafeliners™ (Table 3) (Villers et al., 2010).

**Rice:**
IRRI recommends hermetic storage for all rice growing regions because of reduced losses, improved germination and milling recovery (head rice) (Villers and Gummert, 2009).

**Maize:**
Dry maize stored hermetically in hot, humid climates, as described in *African Farming and Food Processing*, has storage losses of less than 1% and arrests increases in aflatoxin levels (Anon. 2011).

**Cocoa:**
Cocoa is especially susceptible to rancidity (free fatty acids) as well as to insect damage due to its high fat content. As mentioned earlier, the Ghanaian Cocoa Board successfully uses large Cocoons and SuperGrainbags to store cocoa for export (Fig. 6) and, more recently, TranSafeliners™ for protecting cocoa during intercontinental shipments (Jonfia-Essien et al., 2008; 2008b; 2010).


Fig. 6- Cocoon™ for storing 320 tonnes of cocoa at COCOBOD, Ghana, 2012.

## ECONOMIC ANALYSIS

A simple method of comparing the addition of hermetic storage as an alternative to "traditional," non-hermetic containers are shown in Table 2 (Sabio et al., 2006).

Cost effectiveness of hermetic technology is an important consideration for all users. A GrainPro document (#LT2263PV1111-1, unpublished data) provides an interactive calculation of return on investment (ROI) and payback in years.

The costs of various methods used to store rice seed was investigated in the Philippines, an examination which showed hermetic storage to be the lowest total cost alternative (Sabio et al., 2006).

For protection during intercontinental transport of cocoa, Fig. 7, courtesy of Dorman (VolCafe, Kenya), shows a cost comparison of various ways of protecting coffee during shipment.

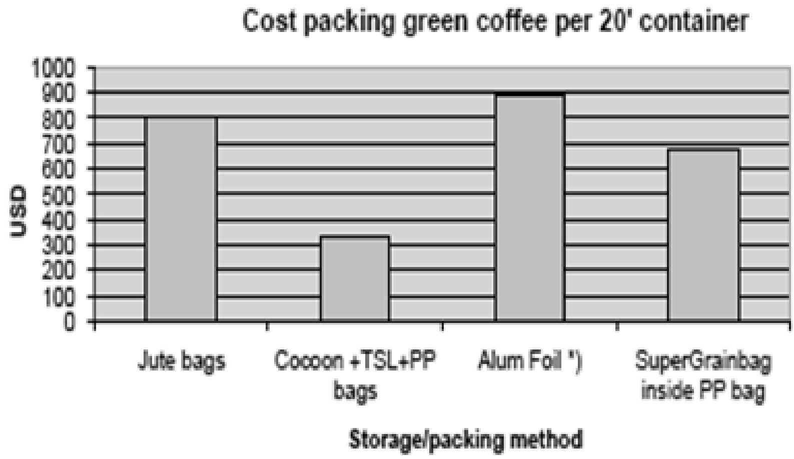


Fig. 7- Dorman (VolCafe, Kenya) shows a cost comparison of various ways of protecting coffee for intercontinental shipments.

## CONCLUSIONS

Hermetic storage, when sufficiently airtight, is a modern, transportable, sustainable, chemical free, user friendly, “green” and cost effective solution to five previously difficult storage problems:

1) Protecting crops from insect infestation;
2) Preventing aflatoxin growth;
3) Preventing rancidity in commodities;
4) Safe, long term storage for quality preservation;
5) Suitable and economic for preservation of seed germination during storage;
6) Eliminating the need for pesticides, fumigants or refrigeration in storage.

Conventional storage in hot, humid climates has failed to protect stored commodities (Villers et al., 2006). Almost 25 years after the introduction of the first hermetic storage systems, countries can now better meet their food security requirements, reduce costs, and increase the incomes of their local farmers.

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