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APPROPRIATE TECHNOLOGY FOR MAINTAINING GRAIN QUALITY IN SMALL-SCALE STORAGE

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ABSTRACT

The quality of rice seed and grain in tropical regions can only be maintained for a short period of time in traditional open storage systems. A combination of poor drying techniques, open storage systems, high relative humidity and high ambient temperatures contribute to a reduction in seed and grain quality during the storage period. In many of these countries it is normal for grain to be re-dried during the storage period and pesticides applied to control insects. Seed can only be kept for 6 months prior to sowing and establishment rates are still often below 10%. Rodents and birds also cause major losses in most open storage systems.

The International Rice Research Institute (IRRI) has undertaken studies in a many Asian countries, comparing commercial and locally manufactured hermetic sealed storage systems with traditional storage systems. Results from these studies have shown that sealed systems prevent the uptake of moisture by the grain from the outside atmosphere, reduce the number of live insects, prolong the viability of seed, and maintain grain quality. These studies have lead to the development of a 50kg super storage bag that fits inside the traditional storage bag and offers all of the attributes of a hermetic system.

INTRODUCTION

The quality of rice seed and grain in tropical regions can only be maintained for a short period of time in traditional open storage systems. Poor drying techniques, insecure storage facilities, and very high relative humidity and temperature contribute to the development of moulds, increased insect activity and faster respiration in stored grain. Even when grain is kept at acceptable moisture levels, insects, rodents and birds still cause major losses. In many tropical countries it is normal for grain to be re-dried during the storage period and insecticides applied to reduce losses.

Storage options: Controlling the equilibrium moisture content of the grain during storage is the most important factor in maintaining a safe storage environment. As grain is hygroscopic it equilibrates with its surrounding environment, and the atmospheric conditions in most Asian countries will cause grain to equilibrate at moisture levels above 14% during the dry season and 15.5% during the wet season.

Management options presently used by farmers include; drying grain to 10-12% and hope that the re-absorption of moisture during the wet season will be slow; using in-store drying or re-drying grain during storage; or drying the seed to a safe level and then sealing the seed from the outside environment.

Sealing the storage system, which is the principal behind hermetic storage systems, has been documented by many authors for controlling grain moisture and reducing the number of insects in stored grain. By placing an airtight barrier between the grain and the outside atmosphere the moisture content of the stored grain will remain approximately the same as when the storage was sealed. The moisture content of the grain will then determine the relative humidity level inside the storage unit. Respiration by the grain and insects inside the storage, change the inter-granular atmosphere by consuming oxygen and expiring carbon dioxide and water. Depending on the number of insects and the size of the system, oxygen levels will be reduced from 21% to less than 10% within a short period of time.

Recent technological advances in plastic manufacturing have led to the development of large commercial PVC liners with airtight seals that provide the required durability to climate and gas permeability, and the physical properties to enable airtight storage for extended periods of time.

Studies have been undertaken by the International Rice Research Institute (IRRI), in a number of Southeast Asian countries by comparing the commercial hermetic storage systems and locally made hermetic systems with traditional storage systems. More recent studies have also examined the use of smaller 3-30kg plastic envelopes.

MATERIAL AND METHODS

Comparative studies examining hermetic storage systems with traditional open storage systems have been undertaken in Cambodia, Philippines, Vietnam, India, Indonesia and Bangladesh. The length of study in each location varied from 12 months to 18 months and measurements were taken every 3 months. The variables measured were oxygen, moisture, live and dead insects, seed germination and milling yields. Oxygen recordings were initially taken daily until levels dropped below 10% and then weekly. In the Philippines, the hermetic storage systems were also compared with cool storage systems. The commercial hermetic systems evaluated were the GrainPro 5,10 and 50 metric ton Volcanic cube, 750 kg GrainPro and the aluminum lined Joseph sack. Locally manufactured systems included 500-liter water containers; 200-litre steel and plastic oil containers, 60-liter and 25-liter plastic containers as well as clay water pots and plastic pouches.

RESULTS AND DISCUSSION

Oxygen content

The rate of O_2 decrease in the sealed containers and bags varied from 0.5-3% per day, see figure 1. The fastest reduction in oxygen levels occurred in Cambodia in 2000 where O_2 levels dropped from 21% to 4% in 5 days. A correlation was not found between, the type and size of container or the number of insects per kg and the rate of oxygen decrease. For example, in 3 different trials in Cambodia, 4 insects/ kg reduced O_2 levels by 1% per day, 8 insects/kg reduced it by 3% per day and 14 insects/kg reduced it by 1.5% per day.

It was also found that when the sealed systems were opened for sampling or grain removal, the second and subsequent reduction in O_2 levels was much slower. In one study where it initially took 30 days for oxygen levels to decrease to 5%, after opening it took 60 days to reach the same O_2 levels, see figure 2.

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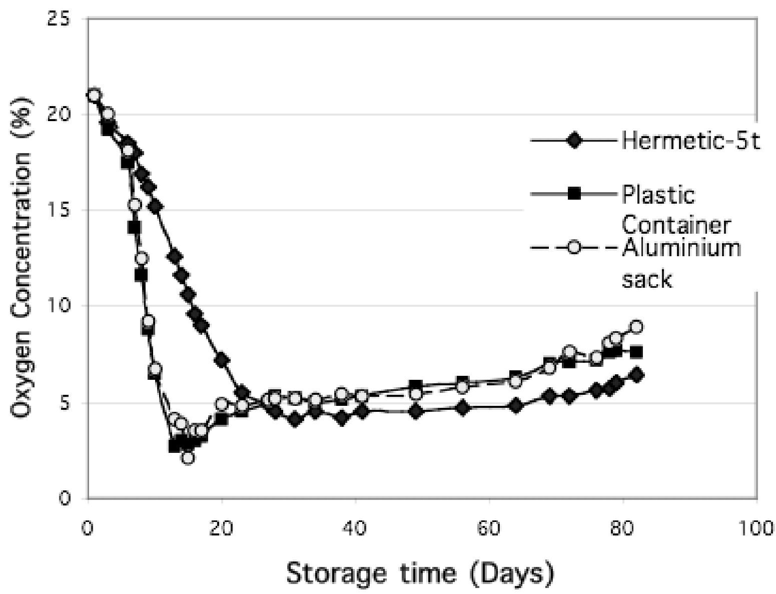

Figure 1: Reduction in oxygen levels for the 5-ton hermetic system, 25-liter plastic container and the aluminum lined Joseph sack

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Plastic storage pouches

Standard plastic storage pouches were compared with medium barrier vacuum pouches at IRRI in 2004. It was found that the standard plastic storage pouches do not prevent the re- entry of O_2 after sealing. Initially the O_2 decreased in the standard plastic pouches at a similar rate to the vacuum pouches, but after 10 days the O_2 levels began to rise and then stabilized at 19%. The oxygen level in the vacuum pouches dropped to 6% after 10 days and then stabilized at 8-9% O_2, see fig. 3.

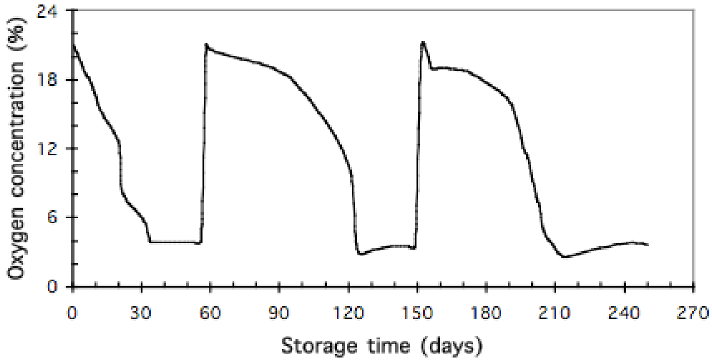

Figure 2: Reduction in oxygen levels after opening and closing the 5-ton hermetic system

Grain Moisture

Changes in grain moisture content depended upon the storage system. Grain moisture levels in the traditional open storage systems fluctuated 2-3% over a 12-month storage period. Using a hermetic system reduced the variation to less than 1.5% while the grain stored in the air-conditioned room decreased by more than 2% over a 12-month period, see figure 4.

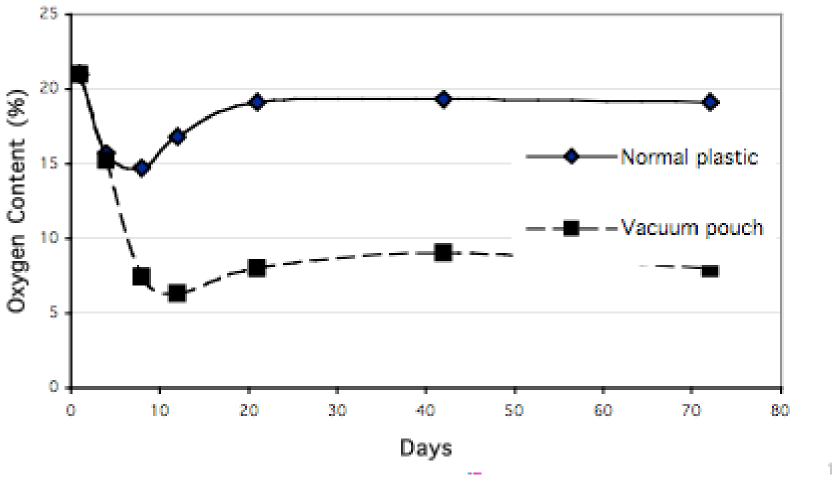

Figure 3: Change in oxygen levels in traditional plastic and medium barrier vacuum pouches

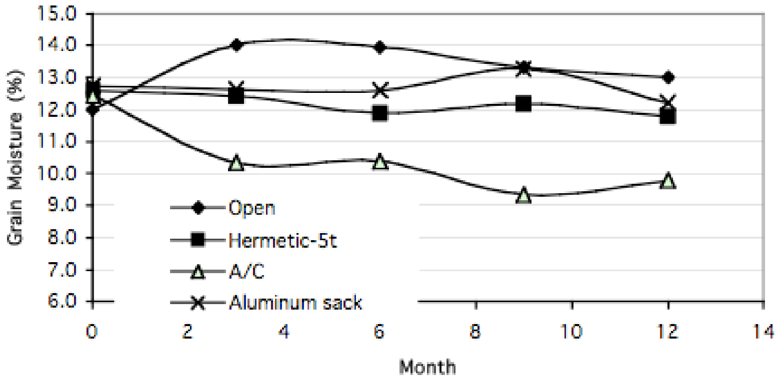

Figure 4: Grain moisture content for different storage systems in the Philippines (2002-3)

It was found in Cambodia that grain moisture levels in clay pots increased by up to 2% when the pots were not properly sealed. In all of the larger commercial systems (5-10 ton) there was no variation in grain moisture levels between the bags stored at the top or bottom of the stack. Previous studies by NAPHIRE in the Philippines, storing grain at moisture levels above 14% found moisture migration in hermetic storage systems which did not have a shade cover

Insect Control

Storage Options

The hermetic storage systems reduced the number of live insects significantly when compared to both the traditional open system and the air-conditioned storage, see table 1. Insects were still able to survive in the air-conditioned storage at 20ºC temperature but not in the cold room at 8ºC. Both the large commercial and the smaller hermetic systems gave similar levels of control.

TABLE 1
: Live insect per 1kg of grain (Philippines 2002)

Months	Open Storage	Air conditioner	Cold room	Hermetic 5ton	25l plastic containers	Aluminium Sacks
0	3.2	8.4	8.4	8.8	7.4	10
3	135	1.6	0	0	1.4	2
6	114	3	0	0.4	1.6	3.6
9	54	3.4	0	0.4	1.2	1.2
12	27	9	0	2.2	1.2	0.2

In Cambodia it was found that when O_2 levels increased above 9%, insect numbers increased. The highest number of live insects recorded was 332/kg in an open storage system in Cambodia

Chemical control

Another solution for controlling insects in stored grain was to dip the storage bags in 2.5% Deltamethin and allow drying before filling with grain. Deltamethin is commonly used in many Asian countries for dipping mosquito nets. This technique was compared with untreated (no control) and the use of phosphine tablets. It was found that phosphine gave good protection for the first 53 days and Deltamethin dipped bags were still giving protection after 159 days, see table 2.

TABLE 2
Live insect /kg using different chemical control (Philippines (2004)

Days	Control	Deltamethrin	Phosphine
0	10	10	7.6
25	30	5	0
53	72	1	0
98	86	1	3.6
125	48	0	11
159	6	0	28.6

Seed Quality

Results from studies in all of the countries have shown that seed stored in hermetic storage conditions have a much longer viable life than seed stored under traditional systems, see figure 5. Studies conducted at IRRI, Philippines showed that seed stored for 12 months under hermetic storage conditions had the same level of germination to that of seed stored in an air-conditioned store. Both systems had 82% germination. In the same experiment seed stored in the traditional bag system had germination levels of 65% after 9 months and only 26% after 12 months.

Similar results were found in studies in Bangladesh, Cambodia and Vietnam. Results in Bangladesh showed an improvement of between 30 to 70% in germination for seed stored by farmers for a 7-month period using hermetic storage. In Cambodia the germination for seed stored in hermetic systems was 90% after 6 months and 63% after 12 months. In comparison, seed stored in the traditional systems had germination levels of 51% and 8% respectively. In Vietnam, seeds stored in tradition woven plastic bags had 0% germination after 7 months while the same seed stored in the hermetic systems had 53% germination.

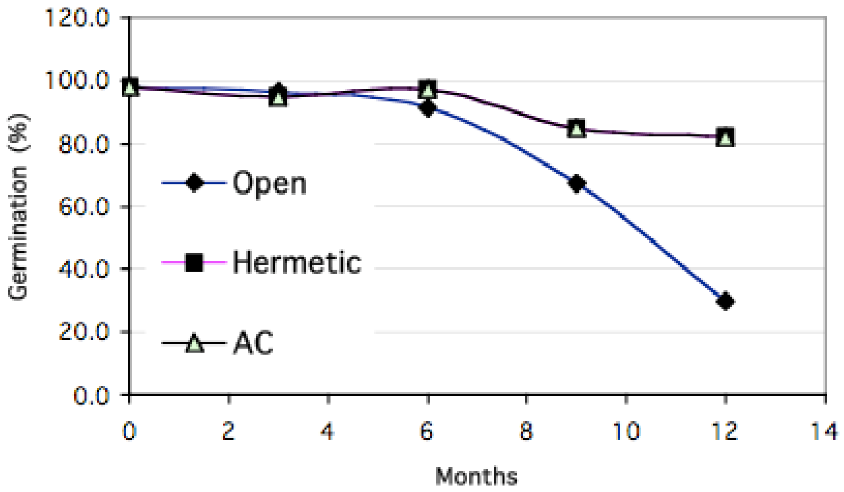

Figure 5. Germination of seed in different storage systems in the Philippines (2002-3)

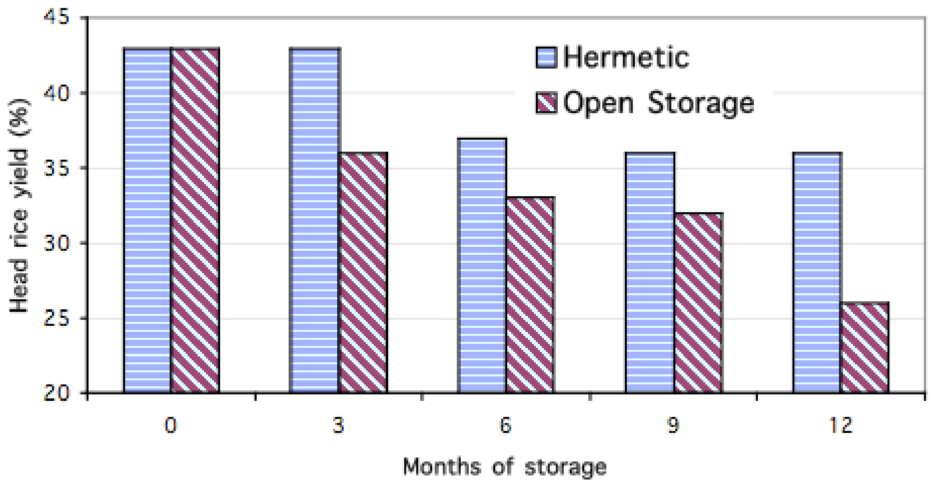

Figure 6: Head rice yields for hermetic and traditional storage systems in Cambodia (2003)

Grain Quality

Grain quality, as measured by head rice yield and the number of broken kernels were higher for the hermetically stored paddy rice than the traditionally stored rice. In Cambodia, head rice yields for hermetically stored grain was 10% higher than the traditional open storage over a twelve month period (see fig. 6). In Vietnam in 2003, there was a 4.5 % reduction in the number of broken kernels after 6-months of storage when using hermetic storage

Grain discoloration

Studies at IRRI over an 18-month period, found that the change in the grain whiteness for the open and hermetic was systems was similar, see figure 7. As expected the grain stored in the cold room showed less change in color over the same time period. It was also noted that the rate of discoloration for hermetic systems was much faster in the first 3 months than all of the other systems.

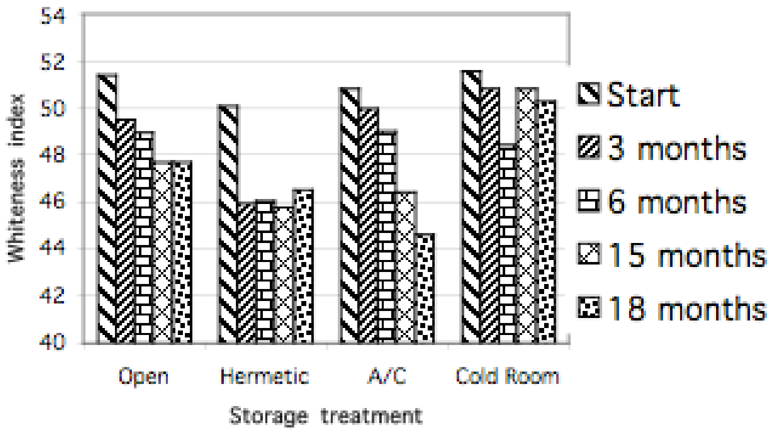

Figure 7. Whiteness index of grain stored for 18 months at IRRI, Philippines. (2002-4)

Other findings

The maintenance of an airtight system was paramount to the success of the storage system. If the seal of the system is broken or the container even slightly damaged O_2 leakage will occur and insects will multiply. In one study the intermittent opening and closing of a 5-ton hermetic system for sampling lead to a rapid re-infestation of the lesser grain borer (*Rhizopertha dominica*). These insects were then able to pierce the PVC liner causing the system to fail. Grease or an airtight sealant must always be used to seal the filler opening of plastic and steel containers. Similarly clay pots must be painted both inside and out before sealing the opening. If the smaller containers are not completely utilized at any one time the air space to grain ratio inside is too large to allow oxygen levels to be reduced sufficiently to control insects

Rodents were able to damage a 50-ton commercial storage at IRRI, Philippines because the plastic liners were not pulled taut and a clear space around the system was not maintained.

Cost

The cost of a hermetic storage system depends on the size of the commercial system or the cost of locally recycled containers or water vessels. The large commercial systems cost from $50-100 per ton capacity to purchase. With an expected life of at least 10 years this equates to a cost of approximately $5-10 per metric ton/year. The cost of locally constructed systems depends on the purchase price of recycled containers or clay pots. 200-litre oil drums cost from $2-5. The plastic reusable super bags cost $1 each.

CONCLUSIONS

Hermetically sealed storage systems are very effective for longer-term storage of rice seed and grain in tropical regions. By stopping air movement from the surrounding environment:

- Grain moisture levels remain fairly constant
- Insect activity is significantly reduced
- The life of seed is effectively doubled and
- The head rice yield is maintained

Hermetic storage systems can be made from any container that can be sealed from the outside environment and has low O_2 permeability. Results indicate that the 50 kg plastic storage pouches offer potential for the smaller Asian farmer – research is continuing at farm level to determine how best to capitalize on this potential.