LOCAL DEVELOPMENT OF A HERMETIC STORAGE CONTAINER FOR QUALITY PRESERVATION OF RICE SEEDS IN THE PHILIPPINES

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Abstract: Experiences in the implementation of the Philippine government's Hybrid Rice Commercialization Program (HRCP) showed that storing rice seeds under a hermetic (gas tight) condition using an imported flexible plastic-lined container can effectively prevent storage pest infestation as well as protect the seeds from the quality-deteriorating effect of high humidity during rainy season. However, the available technology is expensive thus limiting its adoption by the local rice seed producers (RSPs). Hence, this study was conducted to develop a low cost alternative hermetic seed storage technology which can easily be mass fabricated locally. A prototype of a hermetic seed storage container (HSSC), equipped with a simple zipping mechanism, was developed and tested to evaluate its performance in comparison with the other seed storage practices/technologies. Results of the three one-year storage trials showed that the HSSC performed consistently and significantly better than the conventional practice (open-piled bags under ambient condition) and comparably with the imported hermetic container (IHC) in maintaining the viability and vigor of the stored rice seeds (hybrid and inbred varieties) as well as in preventing storage pest infestation.

Keywords*:* hermetic storage; hermetic container; hybrid rice seeds; seed quality; seed storage

INTRODUCTION

The Philippines needs an increased supply of rice primarily because of its growing population. This is a challenge that needs to be seriously taken especially that its rice lands are decreasing due to urbanization and industrialization [1]. Realizing this fact, the government introduced the hybrid rice technology as a new approach for increasing rice production, farmers' productivity and competitiveness, mitigating the negative effects of the *El Nino* phenomenon over the short term, and attaining national food security over the long term [2]. Hybrid rice is known to have a yield advantage of 15% against the inbred varieties, under the same input levels [3].

In 2002, with the implementation of the Hybrid Rice Commercialization Program (HRCP), the commercialization of the hybrid rice technology became the Philippine agriculture's banner program in attaining self-sufficiency and increasing productivity and profitability in rice, and generating rural employment [4]. Since the implementation of the HRCP, more and more farmers are convinced that hybrid rice can indeed increase their yields and incomes. In Northern Luzon, survey showed that farmers get an average net profit which is Php16,069 (~US$ 380) ha^{-1} higher than what they get from inbred rice [5].

Ensuring the availability of good quality hybrid rice seeds at the time farmers need them for planting was one of the critical problems encountered during the implementation of the HRCP. Because of some protocols that had to be followed to ensure the production and distribution of good quality seeds (time isolation in planting, seed certification process, etc.), the availability of the hybrid rice seeds was often delayed and did not match with the time farmers needed them for planting. Because of this, majority of the produced seeds had to be stored for the next planting season. Maintenance of seed quality during storage had been a persistent problem because of inadequate storage facilities. Quality deterioration due to storage pest infestation and exposure of the seeds to high relative humidity during the rainy seasons were the most common problems.

To help solve this problem, the government, through the Philippine Rice Research Institute (PhilRice) being the procurer and the distributor of the hybrid rice seeds during the initial years of the HRCP implementation, adopted, among other things, the use of hermetic storage technology in storing the excess seeds to augment its limited cold storage facilities. This technology makes use of an imported plastic-lined container where the 20-kg bags of hybrid rice seeds were stored inside. It was first adopted in the Philippines by the National Food Authority after being evaluated to effectively preserve the quality of stored milled rice without employing fumigants [6]. Studies also had been conducted for outdoor hermetic storage of corn and paddy and showed that the quality and viability of the seeds was preserved up to six months [7]. Follow-up studies [8] and experiences from actual use of this technology by the authors in storing hybrid rice seeds under the HRCP further confirmed these findings.

Hermetic storage is an environment-friendly technology, involving no hazard to the storage workers, consumers, and non-target organisms. With it, the use of insecticides particularly fumigants, which are being questioned because of their effect on humans and the environment [9] are eliminated. Using this technology, because the container is sealed and impermeable to gases, the stored seeds are freed from the quality-deteriorating effects of humid environments. Moreover, the respiration of the seeds and of the infesting insects lowers down the oxygen concentration to a level where it becomes insecticidal. For the majority of stored product insects and their developmental stages, this oxygen level is within the range of 2% to 4% [10]. The low oxygen environment could control insect infestations but preserve the quality of the grains [11]. On the other hand, high oxygen level tends to hasten viability loss, especially in seeds with high MC [12].

Since the government's intervention on the HRCP was only short term, there was a need to enhance the capability of the hybrid RSPs to store their excess seeds. The establishment of cold storage facilities requires high investments and operating costs such that it is not practical to be used at the level of most local RSPs. In contrast, hermetic storage requires little or no maintenance cost, however, the current technology available in the market is not affordable to the local RSPs as very few has so far invested on it in spite of the known benefits it offers.

While a lot of literatures related to hermetic storage had already been published [13, 14, 15, 16], only few deal on the design and development aspect of the technology, particularly on the kind of material used in a storage container to effect a hermetic condition. One example of these hermetic storage technologies is the one developed by Villers [17] for long term storage of a bulk commodity which utilized a flexible, low permeability sheet material. Further enhancements and variants of this hermetic storage technology was done in succeeding years [18, 19, 20, 21]. On the other hand, Navarro et al. [22] incorporated a compound in the manufacture of a packaging material suitable for use in hermetic storage enclosures. While these technologies have been proven to be effective, these are developed in advanced countries and their adoption in developing countries like the Philippines may be limited due to the low purchasing capacity of the local RSPs who are the target users of the technology. Adhikarinayake et al. [23], on the other hand, attempted to develop an air tight storage bin made of ferro-cement which may be economically feasible for farmers in developing countries. The bin worked well for storing commercial paddy, however, further studies need to be done since the germination rate of stored paddy dropped from 85% to 0% after 6 months of storage.

This paper generally aimed to design and develop a low cost alternative for hermetic storage technology. Specifically, it aimed to:

1. Come up with a design of a flexible HSSC that can be fabricated using locally available materials and fabrication equipment and can perform comparably with the imported hermetic container (IHC).
2. Test the performance of the final prototype of the HSSC together with the existing seed storage methods.

MATERIALS AND METHODS

Prototype design and fabrication. To be able to come up with a low cost technology on hermetic storage, the development of the local HSSC was based on the following design criteria:

1. Allows local fabrication. There were two concerns seriously considered so that the hermetic requirement and ease of mass fabrication could be satisfied: (a) the use of a locally available, inexpensive but durable material, and (b) a simple but durable zipping mechanism;
2. Easy to operate and maintain. The HSSC was designed to be easy to set up as well as repair and maintain by the target users (RSPs) themselves.

Performance evaluation of storage technologies/practices. The technical feasibility of the HSSC was evaluated together with the existing seed storage practices/technologies (Table 1). In all of the storage trials, the rice seeds were contained in the commonly used 20-kg closely woven polypropylene plastic sacks with 0.1mm thick internal polyethylene plastic liner.

1. Conventional storage (CS). In this method, six bags of rice seeds were piled on top of a 0.15m x 1.2m x 1.2m wooden pallet and stored openly under ambient conditions inside a warehouse.
2. Imported hermetic container (IHC). Rice seeds were piled and stored inside a 2.95m x 1.70m x 1.5m (length, width, and height, respectively) flexible container made of 0.83mm Polyvinyl Chloride (PVC)

plastic liner equipped with a multiple tongue and groove zipping mechanism. The pile consisted of eleven layers of bags with 21 bags in each layer.

3. Cold room storage (CRS). The bags of rice seeds were piled on top of a wooden pallet and stored inside a 6m wide x 9m long x3m height cold storage room with digital temperature and RH recorder set at 15^{o}C and 50%, respectively.

Table 1. Storage trials conducted to evaluate the performance of the prototype HSSC together with other existing seed storage practices/technologies.

Trial No.	Storage Practices Evaluated	Rice Varieties Used
1	HSSC and IHC	PSB Rc72H
2	CS, HSSC and IHC	PSB Rc72H
3	CS, HSSC and IHC	NSIC Rc116H & PSB Rc82

Conduct of storage trials. All of the storage practices/technologies evaluated were set up inside a warehouse of the Philippine Rice Research Institute, Munoz Science City, Nueva Ecija, Philippines (approximately 15.71^{o}N latitude and 120.90^{o}E longitude). A total of three one-year storage trials were conducted, one after the other, incorporating prototype design improvements in every succeeding trial based on problems and weaknesses observed in the preceding trial. Seeds of a local hybrid rice variety, PSB Rc72H, were used in the first and second storage trials, being the most abundant hybrid rice seeds available at that time. One kg samples for seed quality analysis were taken from the randomly selected bags representing the top, middle, and bottom portion of the pile. Sampling was done at 0, 3, 6, 9, and 12 months of storage. These samples were analyzed in the PhilRice seed laboratory for various performance parameters discussed below.

Performance parameters. The performance of the prototype HSSC was evaluated and compared with the other storage technologies/practices in terms of the following parameters:

1. *Hermetic capability*. In the absence of appropriate facility for conducting laboratory tests to evaluate the gas tightness of a container, the capability of the prototype HSSC to maintain a hermetic condition was determined by simply monitoring two parameters, namely, the oxygen concentration of the air and the MC of the seeds inside the container. This is based on the theory that, for a hermetic container, there would be no (if not very minimal) exchange of gases between the inside and outside environments thus leading to the reduction in the oxygen level of the air inside the container due to seed and insect (if present) respiration. Likewise, there would also be no significant change in the seed MC since the stocks are isolated from the influence of the humidity of the ambient air. Hence, the hermetic property of the container would have direct influence on the oxygen concentration of the air as well as the MC of the seeds inside the container. In each of the storage trial, monitoring of the oxygen level of the HSSC and of the IHC (as basis of comparison) was done at least three times a week, throughout the one-year storage duration, using a GrainPro® oxygen meter. Wireless and programmable data logger (ERTCO® MicroRHTemp) was installed inside the warehouse to measure the ambient air temperature and RH. On the other hand, seed MC was gathered after every three months where sampling is regularly done to monitor the status of the quality of the seeds. Seed MC was measured immediately after collecting the samples using a G-Won® grain moisture meter earlier calibrated through oven drying method. Three readings were taken per sample and the average was calculated and expressed in percentage of the weight of the original sample (wet basis).
2. *Seed germination and vigor*. The germination percentage of seeds was determined using the rolled paper method while the seed vigor using the accelerated aging test described in the International Seed Testing Association Manual [24].
3. *Degree of insect infestation*. This was evaluated by counting the number of insects, regardless of species, present in a collected sample. For each storage practice, one kg samples were drawn from designated sampling bags that were randomly situated at the top, middle, and bottom layers in the piled bags of seeds. Five hundred-gram samples were gathered from each sampling bag and then put in the freezer so as to kill the live insects and facilitate their easy separation by sieving. Sifted insects were then counted and expressed in terms of their number per kg of seeds.

RESULTS AND DISCUSSION

The test prototypes. The identified locally available material for the prototype HSSC was 0.8mm thick PVC tarpaulin sheet. Based on manufacturers' specifications, this material has the following characteristics: waterproof, high intensity and flexibility, good tensile/tear and peeling strength, with ultra-violet protection, and with resistance to high temperature. No data on gas permeability was available. For PVC materials, however, the O_2 permeability coefficient is 5 cm^3 mm/m^2day Atm 20-25^{o}C [25] which is the lowest among plastic lined materials available in the local market. This material can easily be found in most local stores and sold in per length (width=1.8m) or per roll (total length=50m) basis. Fabrication of the prototypes was done by a supplier of PVC tarpaulin sheets which was also fabricating tarpaulin-based products like outdoor tents, car covers, boat covers, and many others. Fabrication consisted of cutting the sheet into the desired shapes and then welding the edges using an electrically heated tarpaulin sealer.

Table 2 briefly describes the yearly progress made in the development of the HSSC, starting from the first prototype (trial 1) up to the final one (trial 3). For the first and second storage trials, the test prototypes were composed of identical top and bottom components with a simple zipping mechanism that made use of a corrugated flexible plastic tube with longitudinal slit, enabling it to clamp and hold the two joined edges of the two components around one cm distance from the folded section. In trial 1, modeling clay was added at the clamped edges to seal any possible leak, however, this was removed in the second trial since it was found out from a separate laboratory experiments that even without sealing the edges with clay, the clamping tube could already establish a sustained low oxygen condition inside the container. For the third trial, further design improvement was done after noting that the corrugated plastic tube used for the zipping mechanism did not last long. Thus, other alternative materials were being considered which finally lead to the use of Velcro strips. The Velcro strip is popularly used in the garment industry as a good substitute for buttons or zippers. The use of the Velcro strip for the prototype's zipping mechanism demanded a change in the design, from two components (top and bottom) to only one so as to facilitate easy opening and closing. Although a different zipping material was used, the sealing principle adopted in the previous prototypes (i.e. folding and clamping the joined edges together) remained the same. The resulting prototype, which was considered as the final prototype, was also reduced in size to accommodate 50 bags (20 kg/bag) which is the size of 1 seed lot, basing from the Philippine seed certification standards. With this size, the filled container can already be put on top of a standard 1.2m x 1.2m pallet to facilitate movement from one place to another. Figure 1 shows how the final prototype is used.

Table 2. Descriptions of the HSSC prototypes used in each storage trial.

Prototype/ Trial No.	Dimension, m (LxWxH)	No. of components	Sealing mechanism	Capacity, (number of 20-kg bags)
1	1.75 x 1.75 x 1.75m*	2	Clamping the edges with the longitudinal slit of a flexible pipe then sealing the joined edges with modeling clay	200
2	1.75 x 1.75 x 1.2m*	2	Clamping the edges with the longitudinal slit of a flexible pipe, no sealing with modeling clay	144
3	1.35 x 1.35 x 2.05m	1	Velcro strip	48-50

*Dimension of each component

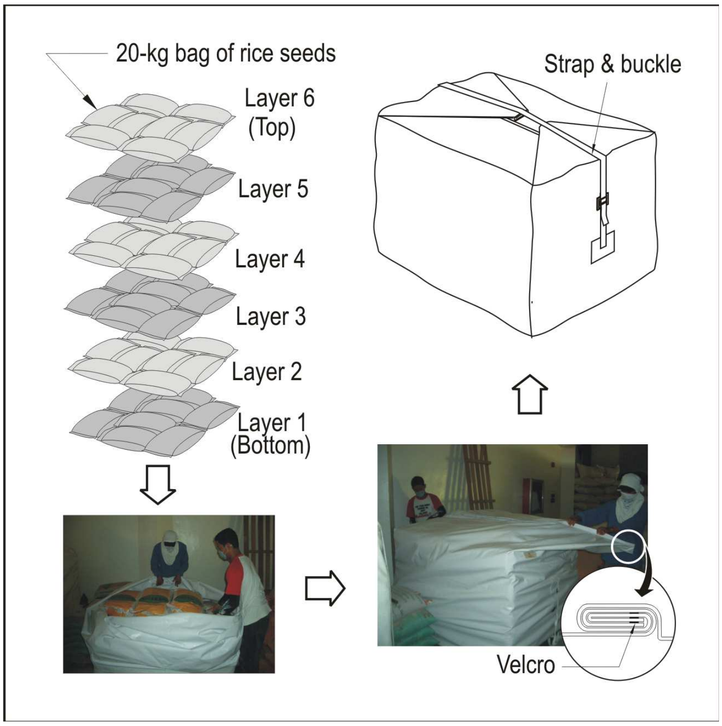

Figure 1. Diagram showing how the HSSC (final prototype) is used.

Prototype performance. In general, basing from the three storage trials conducted, the HSSC prototypes tested were able to maintain a low O_2 concentration as well as low seed MC and insect count which were comparable to that of the IHC and better that the CS. The following discussions however focus more on the results of the third storage trial wherein the performance of the third and final prototype of the HSSC was evaluated and compared with the other storage practices/technologies.

Hermetic capability. Figure 2 shows a profile of the oxygen level inside the two hermetic containers. As shown, the oxygen level of the air inside HSSC is comparable to that of the IHC. The graph shows some peaks (at normal oxygen level of 21%) which were the time the containers were opened for sampling after every 3 months.

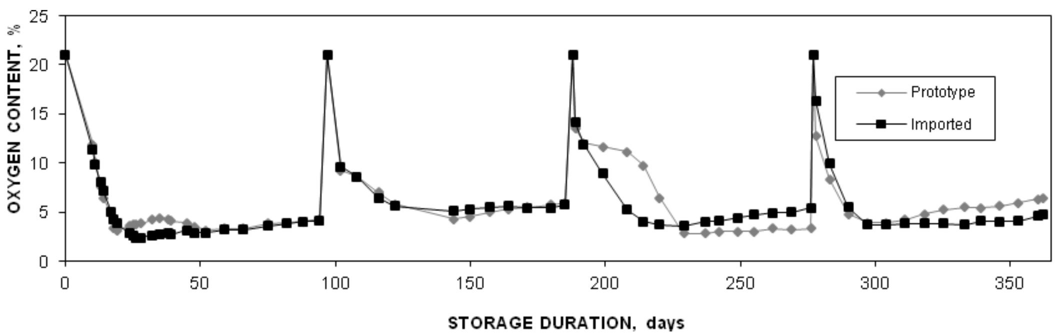

Figure 2. Comparison between the oxygen level inside the prototype HSSC and its imported counterpart.

In all of the three trials conducted, the MC of the rice seeds kept inside the two hermetic containers (IHC and HSSC) did not significantly change after a year of storage, as analyzed statistically. However, for those stored in the CS, particularly referring to the data gathered in the third trial, there was already a significant increase in the seed MC of PSB Rc82 after 6 months of storage (Figure 3). Finally, after 12 months, the seed MC rose 21.6%, an average increase of 1.8% per month starting from an initial MC of 12.73%. The rise in MC for the seeds stored under CS can be attributed to two factors, namely, (a) moisture absorption by the seeds since they were exposed to humidity of as high as 100% during the rainy days, and (b) insect pest infestation.

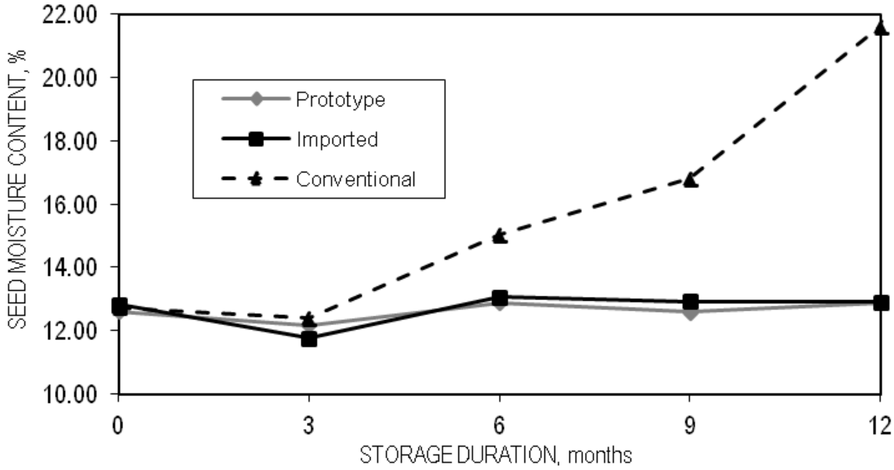

Figure 3. Moisture content profile of PSB Rc72H hybrid rice seed samples taken from the three storage methods every after 3 months.

Seed viability. Overall results of the three storage trials conducted showed that the locally developed HSSC could preserve the viability of stored seeds significantly better than the CS and comparably with the IHC and the CRS. For the third trial in particular, as shown in Table 3, there was already a statistically significant decline in the germination percentage of the conventionally stored seeds after 6 months of storage for the hybrid variety (NSIC Rc116) and 9 months for the inbred variety (PSB Rc 82). This finding conforms to that of Sabio et al. [26] and Chang [12].

Table 3. Seed germination rate of the two rice varieties stored under different storage methods*.

a. NSIC Rc116H (hybrid)

STORAGE METHOD	Months of storage				
	0	3	6	9	12
HSSC	86.13a	91.10a	93.67a	94.90a	94.67a
IHC	86.02a	89.53a	89.90a	88.53a	84.02a
CS	85.93a	91.43a	57.77b	19.23b	3.43b
CRS	85.57a	92.23a	93.10a	92.90a	98.00a

b. PSB Rc82 (inbred)

STORAGE METHOD	Months of storage				
	0	3	6	9	12
HSSC	96.59a	95.00a	95.53a	95.66a	95.92a
IHC	96.75a	94.82a	92.90a	90.26a	85.56a
CS	96.58a	94.32a	86.02a	76.05b	45.03b
CRS	96.70a	95.65a	95.89a	97.13a	97.78a

*Values in a column with the same letter are not statistically different according to Duncan's Multiple Range Test at $p < 0.01$.

Seed vigor. Vigor is recognized as an important seed quality factor distinct from germination [27]. Results of accelerated aging tests to evaluate seedling vigor (Table 4) also showed the same trend as in the percentage germination.

Table 4. Germination of two rice seed varieties stored under different storage methods after being subjected to accelerated ageing tests

a. NSIC Rc116H

STORAGE METHOD	MONTHS OF STORAGE				
	0	3	6	9	12
HSSC	76.33a	91.00a	93.44a	94.56a	87.78a
IHC	75.44a	86.89a	88.78a	86.56a	86.33a
CS	78.78a	89.22a	60.22b	23.44b	7.33b
CRS	71.44a	88.22a	91.78a	93.11a	93.89a

b. PSB Rc82

STORAGE METHOD	MONTHS OF STORAGE				
	0	3	6	9	12
HSSC	94.81a	93.09a	94.91a	96.18a	93.07a
IHC	94.70a	92.59a	92.83a	90.57a	89.74a
CS	93.82a	93.09a	79.98b	77.07b	38.98b
CRS	94.84a	94.21a	96.06a	96.69a	94.53a

Insect count. A combination of rice weevils (*Sitophilus oryzae* L.) and lesser grain borers (*Rhizopertha dominica* F.) was observed in all of the taken seed samples. Among the storage practices/technologies evaluated, CRS did not exhibit a significant increase in insect count for the one year storage period (Table 5). A significant increase in seed count was observed in the hermetically stored seeds starting at the third month of storage but it did not progressed much as compared to the conventionally stored seeds.

Table 5. Average insect count per 500 g sample of seeds from two rice varieties stored under different storage methods.

a. NSIC Rc 16H

STORAGE METHOD	MONTHS OF STORAGE				
	0	3	6	9	12
Prototype	0.33a	3.33a	10.67a	13.33b	22.67b
Imported	0.33a	7.33a	17.33a	75.00c	63.67c
Conventional	0.20a	319.00b	523.67b	749.33d	899.67d
Cold storage	0.33a	1.00a	2.00a	1.67a	5.33a

b. PSB Rc 82

STORAGE METHOD	MONTHS OF STORAGE				
	0	3	6	9	12
Prototype	0.67a	4.00b	3.00b	24.33b	34.00b
Imported	0.40a	12.00b	10.00b	38.67b	41.00b
Conventional	0.67a	225.33c	266.00c	311.67c	302.67c
Cold storage	0.67a	1.33a	0.67a	1.33a	3.00a

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

This study was conducted to locally develop a hermetic seed storage technology for preserving the quality of rice seeds during long term storage.

Results of storage trials conducted to evaluate the performance of the locally developed HSSC in comparison with the imported counterpart (IHC) as well as the other storage technologies/practices (CS and CRS) showed that the HSSC could preserve the quality of stored inbred and hybrid rice seeds comparable with that of the IHC and significantly better than the CS method. The study only focused on evaluating the performance of the HSSC based on the practical aspects particularly on how they perform at the target users' perspectives. Follow up laboratory trials need to be done to have a deeper understanding of its capability and performance relative to the imported counterpart particularly in terms withstanding the leak tests, determining both the O_2 and CO_2 concentration of the air inside it during actual usage.

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