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Hermetic Bag: An Effective Storage Technology for Rice Seed/Hermetic Bag: A Key Element in Enhancement of Food Availability

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Abstract: Hermetic bag (HB) has emerged as a significant alternative to other methods of storage. The study was conducted to compare traditional storage system along with HB bag in Bangladesh Agricultural University in completely randomized design with three replications of six treatments – *Dole*, *Motka*, Plastic Drum, Plastic Bag, HB i.e. Perdue Improved Crop Storage (PICS) and GrainPro Bag. The changes of moisture content (MC) of stored rice were found maximum in *Dole*. Because upper surface of it is open and paddy is hygroscopic. Whereas, MC remained same (12%) in GrainPro and PICS bags during five months. Since these are airtight and prevent moisture exchange with surrounding. Increased moisture, high temperature and relative humidity favored insect infestation in traditional storage technologies. Consequences, the highest storage loss of stored rice was found in *Motka* followed by *Dole* and plastic bag undoubtedly due to persistence of high MC and oxygen whereas no insect infestation was observed in HB. Due to porous behavior of *Dole, Motka* and Plastic bag permits serious loss by insects than that in HB. Germination capacity fell down to 42% in *Dole.* It was observed (≥ 92%) in HB. Highest financial benefit can be obtained using PICS Bag followed by GrainPro Bag and Plastic Drum. HB made insecticide use redundant in paddy storage, maintain seed viability. However, HB may be adopted widely at farmers' level for ensuring quality seed and enhancing food availability.

Keywords: Hermetic, Effective, Profitable, and Technology

1 Introduction

Hermetical Storage generates an oxygen-depleted, carbon dioxide-enriched atmosphere caused by the respiration of stored paddy and the living organisms. It restricts moisture migration from the environment to the grain, protection from rodents, reducing losses of germination of grain. The technology is suitable for storage of a variety of seeds to preserve germination potential and vigor. In Bangladesh, farmers generally store paddy in traditional storage technologies which are not durable or functional and stored paddy seed in such technologies is subjected to damage due to biological, environmental and other factors. Seed is one of the vital inputs for crop production. Using good quality seed, rice yield could be increased by 15% to 20%. In Bangladesh, more than 80% of the rice seeds are produced and preserved by farmers Fakir *et al*., (2004). In most cases farmer's stored seeds are badly infested with stored grain pests and moulds with very poor germination (Mia *et al*., 2000). Food availability refers to the physical presence of food at various levels from house hold to national level, be that from own production or through markets (FANTA,2006).The net availability of paddy is considerably less than its gross production due to all these factors. Abundance of O_2, high temperature and relative humidity promote the growth of insect population and molds caused quality deterioration. These problems are eliminated through the lethal effect of a low O_2/ high CO_2 atmosphere produced through respiration processes. Under hermetic conditions, stored commodities with intermediate moisture contents generate modified atmospheres due to the respiration of the microflora and the commodity itself. Hermetic storage protects especially seeds from different infestations. Many studies in colder regions with distinctive cold seasons have found that this type storage maintains germination of 85% or more for the periods up to 9 months, while conventional storage in jute bags reduces germination down to 14% to 76% within 3 months. Few researches conducted on benefits of hermetic storage in Philippine, Mexico and found better in their climate context. Bangladesh faces a different challenge in paddy storage in terms of warm temperatures (10°C to 37°C) and high ranges of relative humidity (43% to 89%) which favors rapid insect infestation (Hossain *et al*. 2017). How much feasible the hermetic storage is in Bangladesh context, ingress rate of O_2 or CO_2 level is sufficient to arrest the insects' damage should be answered? No study has been available in scientific arena of the feasibility of hermetic bag. Therefore, the study has been undertaken to assess hermetic bags in paddy storage in hot and weather of Bangladesh.

2 Methodology

The study was carried out in the Department of Farm Power and Machinery (DFPM) postharvest preservation and processing laboratory, Bangladesh Agricultural University (BAU), Mymensingh.

Properties of hermetic bags

Thickness, tensile and seal strength of hermetic bags were determined with Micrometer; Universal, Seal Strength, Water Vapor Transmission Rate (WVTR) testing machine, respectively. Produced O_2 and CO_2 concentration in stored paddy in GrainPro, PICS and locally available polythene bags was measured using a Mocon PAC Check Model 325 headspace analyzer.

Moisture content

Moisture content of paddy was determined by digital moisture meter, Moisture Check PLUS^{TM}, SW08120. Moisture content was expressed as percentage.

Determination of storage loss

Storage loss of paddy was measured by the weight of paddy before (A) and after storage (B) (Gangwar and Singh, 2007 and Basavaraja, Mahajanashetti and Udagatti, 2007), (FAO, 1980).

$$\text{Loss of storage} = \frac{A - B}{A} \times 100\%$$

Germination test

Germination (%) of sample was determined on sand media in plastic box following the International Seed Testing Rules (ISTA, 1999).

Partial budgeting of different technologies in paddy storage

Gross margin of different storage technologies through partial budgeting for seed purposes was estimated according to Table 1. Positive effect is the sum of total additional income and total reduced cost by the proposed technology. Negative effect is the sum of total reduced income and total additional cost of the existing technology. And gross margin is the difference of positive effect of proposed technology and negative effect of existing technology. Positive difference in gross margin indicated the additional amount of financial benefit can be earned by the proposed technology than the existing one.

Table 1. Estimated gross margin through partial budgeting for seed purpose

Source: TAI=Total Additional Income; TRC=Total Reduced Cost; TRI=Total Reduced Income; TAC= Total Additional Cost; Total A= Sum of Positive effect; Total B= Sum of Negative effect

Changes from Plastic Drum to PICS Bag				**Changes from *Dole* to Plastic Drum**				**Changes from Plastic Drum to GrainPro Bag**			
Positive Effect	Value (Tk.)	Negative Effect	Value (Tk.)	Positive Effect	Value (Tk.)	Negative Effect	Value (Tk.)	Positive Effect	Value (Tk.)	Negative Effect	Value (Tk.)
TAI		TRI		TAI		TRI		TAI		TRI	
TRC		TAC		TRC		TAC		TRC		TAC	
Total A		Total B		Total A		Total B		Total A		Total B	
Change in gross margin: Total A minus Total B				Change in gross margin: Total A minus Total B				Change in gross margin: Total A minus Total B			

3 Results and discussion

Properties of hermetic and locally available seed bag

Thickness of PICS, GrainPro and locally available seed company bags were found 95-100, 75-80, and 104-107 micron, respectively. Tensile and seal strengths of those bags were found 13.33, 19.55; 7.42, 13.33; 13.91, 44.19 g/mm^2, respectively. Water vapor transmission rate of PICS, GrainPro, and locally available seed company bag was found 0.07, 0.09 and 0.51 g-m^2/day, respectively.O_2 concentration level of stored paddy in PICS bag was decreased from 20.76% to 20.6% slightly upto fourth days then sharply decreased to 6.04% within third week (21^{th} days) of storage and dropped to 3.38% with slight fluctuations until 28^{th} days. In the mean time, CO_2 concentration (0.18%) sharply increased to 10.5% in 21^{th} days and then rose to 13.01% in 28^{th} days (Figure 1(a)). In GrainPro bag, O_2 concentration (20.76%) level in stored paddy was decreased slowly to 18.07% upto 17^{th} days of storage then drastically fell to 4.71% within fourth week (28^{th} days) of storage. Meanwhile, CO_2 concentration (0.19%) gradually increased to 1.96% until 17^{th} days and then sharply rose to 10.26% in 28^{th} days as shown in Figure 1(b). Hermetic storage is based on the principle of generation of an oxygen depleted, carbon dioxide-enriched interstitial atmosphere caused by the respiration of the living organisms in the ecological system of a sealed storage. In locally available company seed pack (ACI Limited), O_2 and CO_2 concentration level in stored paddy was remain constant at 19.78 and 0.20% during storage, respectively.

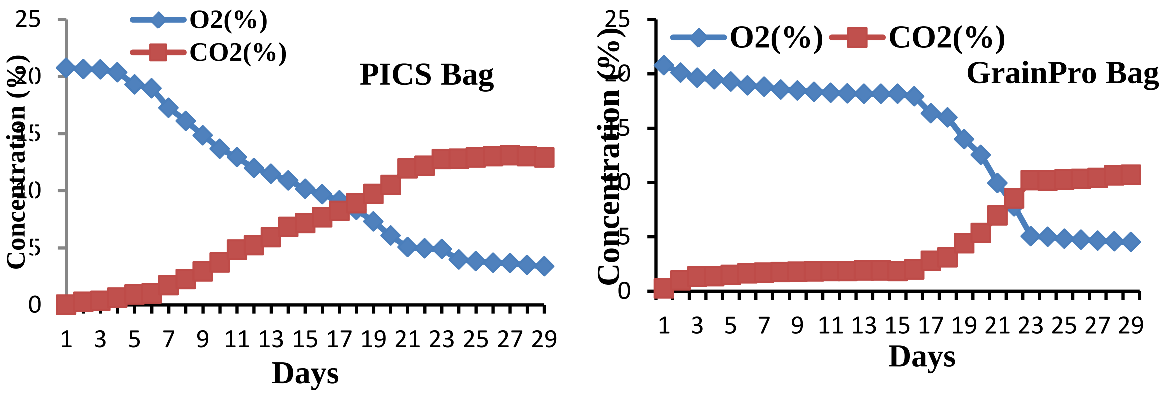

Figure 1. O_2 and CO_2 concentration in stored paddy in a) PICS and b) GrainPro bags

Moisture content of stored *Boro* paddy

The changes of initial moisture content (12%) in stored *Boro* paddy after five months of storage under different storage technologies (*Dole, Motka*, Plastic Bag, Plastic Drum, GrainPro Bag and PICS Bag) is presented in Figure 2. Maximum moisture content was recorded in *Dole* (15.6%) followed by *Motka*, Plastic Bag, Plastic Drum and GrainPro Bag (12.7%). And minimum moisture content was found in PICS Bag (12.5%). Rate of change of moisture content was higher in *Dole* followed by *Motka*, Plastic Bag, Plastic Drum and GrainPro Bag. Moisture content was remained almost same in PICS Bag during storage. Air temperature and relative humidity in storage room varied in magnitude with fluctuations of outside temperature and relative humidity. Moisture content of seed is dependent on the relative humidity of the storage room. It increased highly in *Dole*, *Motka* and Plastic bags and was almost stable in the Plastic Drum. Its pattern was observed almost unchanged for stored paddy in hermetic bags (HB) i.e. GrainPro and PICS bags. Changes in paddy moisture content depended upon the storage system. Paddy moisture levels in the traditional storage technologies fluctuated 2-4% over traditional storage. Using a hermetic system reduced the variation to less than 1%. The lower variation of moisture content of seed was maintained by PICS Bag followed by GrainPro Bag and these moisture data were not significantly different. Increase or decrease in moisture content of stored paddy was not same in all storage technologies due to the differences of vapor transmission capacity of those. The storage technology having higher vapor transmission rate facilitated higher increase or decrease in the moisture content of the stored paddy. These results indicate that hermetic bag maintained the equilibrium moisture content of seeds compared to that of traditional technologies. Similar result was reported by (Kreyger, 1963) who observed that, in sealed containers, the moisture content of the seeds determines the humidity of the internal atmosphere. Under such conditions dry seeds can not absorb moisture from the external atmosphere. Controlling the equilibrium moisture content of the grain during storage is the most important factor in maintaining a safe storage environment. As paddy 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 15.5% during the wet season. PICS and GrainPro bags are found effective in controlling of moisture, CO_2 and O_2 concentration exchange of stored paddy in hermetic bags with outside atmosphere. Puffed rice and ACI seed bags are not suitable for seed storage as there is no O_2 barrier in these polyethelyne bags.

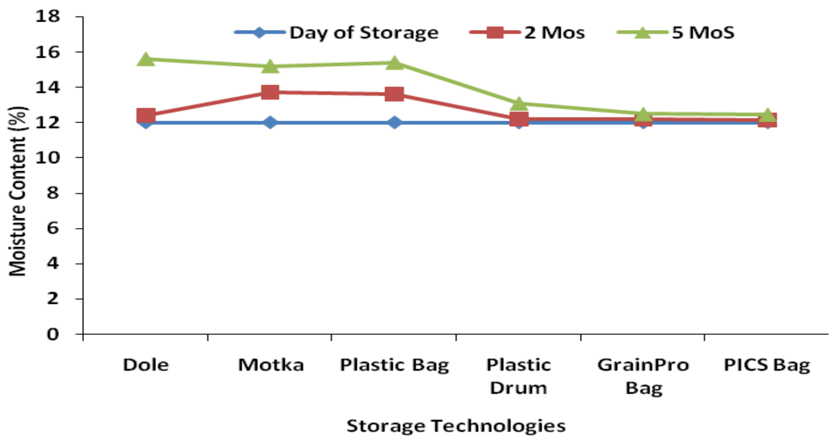

Figure 2. Changes of moisture content of paddy at different period of storage

Storage loss of paddy and possible reduction

Storage loss of paddy occurred due to insect infestation and weight loss. The highest percentage storage loss of paddy was found 6.27% in *Motka* after five months followed by *Dole*(6.00%), Plastic Bag (4.74%), Plastic Drum (1.12%), GrainPro and PICS Bags (0.05%) as shown in Figure 3. Storage loss of paddy can be reduced by 6.47% using PICS bag followed by GrainPro bag, Plastic drum, Plastic bag and *Dole* (0.57%), respectively over *Motka*. Highest amount of storage loss can be reduced using hermetic storage followed by Plastic drum, Plastic bag and *Dole* over *Motka*. Storage loss of paddy occurred due to insect infestation and weight loss. Storage loss of paddy due to insect infestation was found maximum at *Motka* followed by *Dole*, Plastic Bag and Plastic Drum in stored paddy both in *Boro* season. Thakur and Gupta (1996) and Mandal *et al*. (1984) also made similar observations. No loss due to insect infestation was occurred in stored paddy of GrainPro and PICS Bags. Almost similar observation was given by Howlader *et al*. 2004, Mia *et al*. (2003). Fakir *et al*. (2003) also stated that the number of insect population during storage varied with respect to storage containers, storage period and additives used. No significant difference was observed between GrainPro and PICS bags.

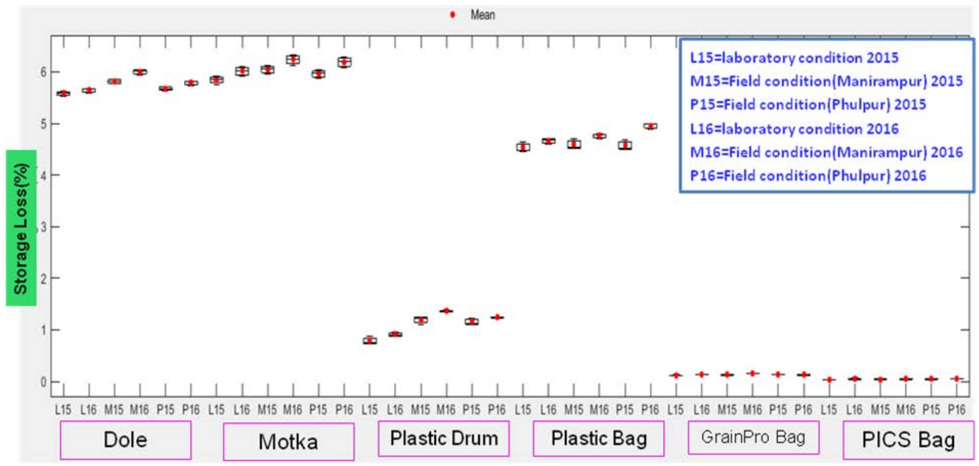

Figure 3. Loss of stored paddy in different storage technologies

Germination percentage

During storage, germination of stored paddy was found 97%. It showed that storage technologies have effect on germination of paddy. In *Boro* season, highest germination percentage was recorded in PICS Bag (93%) followed by GrainPro Bag (92%), and Plastic Drum (81%) (Figure 4).Germination was found less than acceptable limit (80%) in *Dole*, Plastic Bag and *Motka*. Germination of stored in *Motka* produced lowest germination (62%). Storage technologies showed significant effect on germination of paddy. In *Boro* season, highest germination percentage was recorded in PICS Bag (92%) followed by GrainPro Bag, and Plastic Drum (~80%) which is within the standard of Bangladesh. Percentage of germination was found less than acceptable limit (<80%) in *Dole*, Plastic Bag and *Motka*. The decline was the highest of stored paddy in *Motka*. Germination percentage of stored paddy was decreased due to insect infestation. At the onset of storage paddy germination was counted 97%.The possible reason for heavy loss of germination in *Motka* as being black painted from outside to the attraction of insect might have been maximum which lead to highest germination loss. The minimum damage of was observed in hermetic bag because it good barrier in moisture and oxyzen movement. Higher germination rates were observed in hermetic bags. A decline in paddy seed germination with time is in conformity with the results discussed by Huynh Van Nghiep *et al*. (2005). IRRI showed safe storage in the smaller SuperGrain bags (60 kg) (Rickman and Aquino, 2004; Villers and Gummert, 2009). Other studies on hermetic storage of paddy and corn seed in Mexico, Thailand, Bangladesh, and Cambodia showed similar results for periods of 90-280 days with germination rates at the end of the period from 95 to 98.3% (Jonfia *et al*., 2010). Degeneration of vital enzymes due to denaturation and coagulation of protein molecules during storage may be possible reason for decreased germination in cereals (Weidner *et al*., 1996). For paddy and maize, germination of seed was 85% or more for periods up to 9 months, while conventional storage in jute bags reduced germination to 76% to 14% within 3 months (Villers *et al*., 2010). According to Ching*et al*. (1960), impermeable containers keeps seed moisture content lower but in permeable storage containers seed moisture content goes up gradually during storage reducing seed quality depending on reduction in germination percentage. At 15.5% moisture level invasion of storage fungi and germination percentage reduction of paddy were proportional to increasing moisture content and the length of storage. Rahman *et al.* (2003a) reported that moisture content and germination of farmers stored paddy seeds varied from 11.7% to 16.5% and 61% to 78%, respectively with respect to containers which is similar to this study. So, hermetically paddy storage may be good option in Bangladesh for getting quality seed.

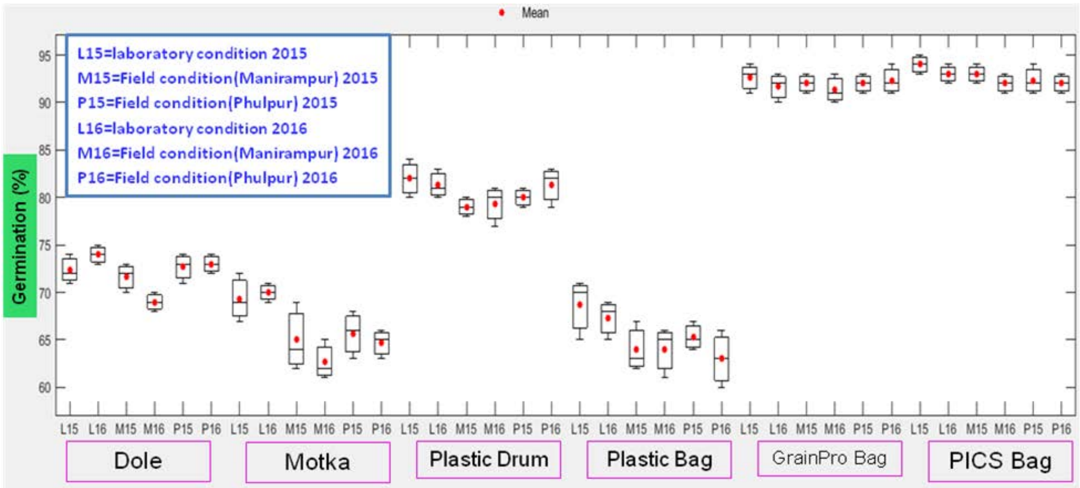

Figure 4. Germination of stored paddy in different storage technologies

Substitution proposition of selected paddy storage technologies

Table 2 indicated PICS Bag is the best technology financially than that in GrainPro Bag, *Motka* and Plastic Bag in paddy seed storage. If a farmer uses PICS Bag in paddy seed storage, can gain Tk. 66,710/ton/yr followed by *Motka*, Plastic Bag, Plastic Drum and GrainPro Bag(Tk. 65,410/ton/yr). The substitution propositions among the selected storage technologies indicated that hermetic bags i.e. PICS and GrainPro bags over other traditional storage technologies for seed purpose storage appeared as the most impressive. Farmers who wish to store paddy, either of the technology he can choose among two types of hermetic bags, taking into account price, profitability and durability. Hermetic storage appeared as an alternative to traditional technologies are found (Sabio *et al*., 2006). Cost effectiveness of hermetic technology is an important consideration for all users provides an interactive calculation of return on investment (ROI) and payback in years (De Bruin *et al*., 2012). The costs to store rice seed was investigated in the Philippines, observed hermetic storage to be the lowest total cost alternative (Sabio *et al*., 2006). Economic benefits improve at the farm level food and health security by virtue of reduction in storage loss; and ability to hold crops until market selling price is high.

Table 2: Substitution proposition of selected paddy storage technologies in seed storage

	Plastic Bag	Plastic Drum	GrainPro Bag	PICS Bag
Motka	Tk.13940/ton/yr	Tk. 27980/ton/yr	Tk. 65410/ton/yr	Tk. 66710/ton/yr
Plastic Bag		Tk.14040/ton/yr	Tk. 51470/ton/yr	Tk. 52770/ton/yr
Plastic Drum			Tk. 37430/ton/yr	Tk. 38730/ton/yr
GrainPro Bag				Tk.1300/ton/yr
PICS Bag				

4 Conclusion

Hermetic bag can be an appropriate method for rice seed storage which eliminates the use of insecticide. In traditional storage technologies, MC of paddy increased highly in *Dole*, *Motka* and Plastic Bag; slightly in Plastic Drum. Paddy is hygroscopic, equilibrates with surrounding environment receiving moisture. As a result, in traditional storage technologies insect populated massively cause major storage, germination and financial losses. Whereas moisture content remained constant (12%) in GrainPro and PICS bags during five months of storage, because, these bags were airtight and stored rice of it did not absorb moisture from the atmosphere. After five months of storage, average germination capacity was fall down to 42% in *Dole*, however, it was above acceptable range (≥ 92%) in HB. PICS and GrainPro bags were found as hermetic while locally available seed bags had not such trait. HB can reduce germination and storage loss, maintain seed viability. In paddy seed storage, GrainPro and PICS bags was obtained economically profitable. Hermetic bag appeared as an alternative to traditional technologies.

Acknowledgement

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