Annals of the Sri Lanka Department of Agriculture 2011. 13: 59-70.

HERMETIC STORAGE METHOD, A PROMISSING ALTERNATIVE FOR RICE STORAGE

R.F. HAFEEL[1], B.D.R. PRASANTHA[2], D.M.N. DISSANAYKE[3], and E.M.R.D. EDIRISINGHE[4]

[1]*Rice Research Station, Ambalantota, Sri Lanka*
[2]*Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka*
[3]*Rice Research and Development Institute, Batalagoda, Ibbagamuwa, Sri Lanka*
[4]*Registrar of Pesticides Office, Peradiniya Road, Peradiniya, Sri Lanka*

ABSTRACT

To the study evaluated the grain quality of rice (*Oryza sativa*) varieties Bg 352 and Bg 300 stored in hermetic storage bags and common poly-sacks. Rice seeds with 12±1 % moisture content were stored in hermetic "IRRI-super bags" and in common poly-sacks at an air temperate of 30±5 °C and a relative humidity of 80±5 % for 4½ and 9 months. After storage, the samples were tested for CO_2 and O_2 concentration inside the bag, grain moisture content (MC), thousand grain mass (TGM), polished rice grain whiteness (WH), fat content (CF), free fat acidity (FFA) and sensory qualities. Oxygen content dropped to 13.7 % and 12.3 % and carbon dioxide content rose to 2.4 % and 2.7 % in the hermetic IRRI-super bag after 4½ and 9 months of storage, respectively. The results showed that MC of the poly-sack stored paddy increased significantly ($p<0.05$) compared to IRRI-super bag. There was a significant decrease of the TGM in poly-sacks. After 9 months, an improvement in milling quality of rice grains was observed in hermetic storage than poly-sack storage. Due to the low MC and O_2 accumulation, high CF and low FFA were observed in hermetic storage compared to poly-sack and tenderness of rice was ranked comparatively higher in hermetic storage. However, varietal differences were observed in all measured parameters under the test conditions. Results of this study suggest that hermetic storage could be used to store paddy up to 9 months as an effective method to overcome rice grain quality deteriorations in storage.

KEYWORDS: grain quality, hermetic storage, poly sack, rice

INTRODUCTION

Sri Lankan farmers store paddy for a period of 6 to 12 months for own consumption, seed for the next season and future sale (Adikarinayake, 2005). At present, paddy is commonly stored in poly-sack bags but to a limited extent, traditional storage methods are also used. However, on-farm storage contributes to the largest postharvest losses of paddy, which is nearly 4-6 % due to adoption of improper storage techniques and lack of proper storage facilities (Fernando *et al.*, 1985; Sartaj and Ekanayake, 1995). Insect infestation causes significant damage to quality of paddy during storage (Trematerra *et al.*, 2004) and tends to speed up the undesirable chemical changes on stored grains and their products (Smith *et al.*, 1971; Seitz and Sauer, 1996). Therefore, deterioration of paddy/rice quality is unavoidable under common storage systems.

Hermetic storage is considered as a promising alternative to fumigation storage system under tropical conditions (De-Lima, 1990; Donahaye *et al.*, 2001a). Donahaye *et al.* (1991) first investigated the possibility of storing bagged paddy/rice under tropical outdoor conditions in Sri Lanka using sealed plastic liners. In hermetic storage, the atmosphere is been modified by sealing the container so that a gas composition of low O_2 and high CO_2 inside the container could be created after few weeks of storage (Busta *et al.*, 1980). The alteration of the stored atmosphere gas composition is achieved through metabolism of the grain, insects and fungi present in the stored grain. Therefore, insects enclosed in the stored grain die off due to lack of oxygen and high carbon dioxide developed inside the hermetic storage system (Emekci *et al.*, 2001). Further, the growth of fungi, which may produce aflatoxins is inhibited (Caliboso and Sabio, 1998). According to the previous studies, losses are less when paddy/rice is stored under hermetic conditions but few studies have been carried out to evaluate the relationship between paddy/rice stored under hermetic storage and changes in the grain quality parameters (Gras and Bason, 1990; Ben *et al.*, 2006).

There is an increasing demand for quality rice in the national and international markets at present. To fulfill the market demand on quality rice, a thorough investigation should be done under local conditions to evaluate the grain quality changes in hermetic storage system especially with "IRRI-super bags". Therefore, the objective of the present study was to investigate the effects of hermetic storage using "IRRI-super-bag" on grain quality parameters of rice in comparison to storage of paddy using common poly-sack bag for 4½ and 9 month storage periods.

MATERIALS AND METHODS

Paddy harvested from the previous season was sun dried to 12±1 % moisture (wet basis) and cleaned and disinfested using chloroform ($CHCl_3$) vapor in a gastight chamber prior to initial testing and storage. Two kg from each of the most popularly grown rice (*Oryza sativa*) varieties in Sri Lanka, Bg 352 and Bg 300 were stored under each of two different types of storage conditions namely "poly-sack" (polypropylene of *Danier* 1850) bags as the control and "IRRI-super-bags" for hermetically-sealed storage over two storage periods namely. 4½ and 9 months. Therefore, there were altogether five storage conditions. *i.e.* 4½ month poly-sack, 4½ month hermetic, 9 month poly-sack, and 9 month hermetic, compared with the initial conditions. The IRRI-super bags of the International Rice Research Institute (IRRI), Philippines, are highly impermeable to air (O_2 permeability 55 $cm^3/m^2/day$) and moisture (8 $g/m^2/day$) diffusion thorough the material (Bakker *et al.*, 2003; Anonymous, 2005).

Prepared paddy samples were stored in a cleaned and disinfested empty warehouse, where the average air temperature was 30±5 °C and the air relative humidity (RH) was 80±5 %.

Hermetic condition

Oxygen and carbon dioxide concentrations in IRRI-super bags were monitored using a gas analyzer (model: ICA 15 Dual Analyzer). The ambient temperature and RH inside the storage bags were monitored using thermocouples and RH probes (model: TC Pico Tech) connected to a data logger (model: TC PicoTech).

Moisture content (MC)

The initial and end of storage moisture content (MC) of rice grains were measured at the end of each storage period using a calibrated digital grain moisture meter (model: GMK 303).

Thousand grain mass (TGM)

Thousand grains from all treatments were counted using a digital grain counter (model: 6708-Indosaw), weighed separately to determine thousand grain mass (TGM).

Milling parameters

One hundred and fifty grams of paddy was passed twice through a laboratory rubber roll sheller (model: Satake) for dehusking and brown rice was then polished for one minute by using an abrasive type polisher (model: 2 TX McGill). The total milled rice was passed through a sieve to remove broken grains and further separation was done manually. Milled rice kernels that are at least two-third of the original kernel length was considered as head rice. The percentages of brown rice (BR), total milled rice (TMR) and head rice yield (HRY) was expressed according to Cruz and Kush (2000).

Grain whiteness (WH)

The degree of whiteness (WH) of milled rice samples was measured using a whiteness meter (model: C-300 KETT). Whiteness meter was calibrated using a standard white plate having whiteness value of 83.4. The standard plate was used in between each and every sample measurement.

Crude fat content (CF) and free fat acidity (FFA)

Using two grams of rice flour, fat extraction was done according to Min and Steenson (1998). Free fat acdity was determined by the rapid method published by the American Association of Cereal Chemists (AACC, 2000).

Sensory quality characteristics

Washed rice was cooked in a 300 ml mini rice-cooker (SR-03G National, Japan) and kept in "warm" for 10 min and served for a panel of 30 semi-trained panellists at the Rice Research and Development Institute (RRDI), Batalagoda, Sri Lanka, to evaluate taste/tenderness using a 5-point hedonic scale test.

The experiment was arranged in a two factor factorial (2 paddy varieties x 5 storage conditions) in a CRD with 3 replicates. Data were analyzed using ANOVA procedure and means were compared using DMRT.

RESULTS AND DISCUSSION

Hermetic condition

The average temperature and RH of paddy grains of both varieties stored in hermetic IRRI-super bags were 30±2.5°C and 70±2 %, respectively. The temperature and RH within the poly-sacks (control) were similar to ambient condition which was 32±3 °C and 80±5 %, respectively. Oxygen concentration dropped from the 21 % ambient level to 13.7 % after 4½ months and then to 12.3 % at 9 months while the CO_2 concentration increased from 0.03 % ambient level to 2.3 % at 4½ month and 2.7 % at 9 months in hermetic storage. The O_2 and CO_2 concentrations inside the poly-sack bags were similar to the ambient air conditions of 21 % and 0.03 %, respectively. Caliboso and Sabio (1998) and Ferizli *et al.* (2001) have observed an increase in CO_2 above 12 % within 3-4 weeks of hermetic storage of paddy with artificial infestation of some stored pests.

Moisture content

After 4½ months of storage, the average MC of Bg 352 and Bg 300 stored in the poly-sacks increased from 12.47 % and 12.03 % to 13.07 % and 13.1 %, respectively, but in hermetic IRRI-super bags the MC increased only up to 12.6 % and 12.9 %, respectively (Table 1). Ben *et al.* (2006) reported that the increase of MC in IRRI-super bags was probably due to the respiration of grains. After 9 months of storage, the MC of stored paddy increased significantly further in poly-sacks up to 13.30 % in Bg 352 and 13.37 % in Bg 300. Paddy stored in poly-sacks has increased the MC through moisture

Table 1. Grain quality parameters of two rice varieties under different storage conditions.

Variety and Storage Method	*MC*	*TGM*	*BR*	*TMR*	*HRY*	*Crude Fat %*	*Acid Number (mg KOH/100DM)*
Bg 352							
Iniltial	12.47± 0.15^{c}	26.2± 0.69^{a}	78.7 ± 0.4^{d}*	71.30 ± 0.1^{c}*	49.9 ± 1.2^{b}*	2.44 ± 0.08^{a} *	0.53 ± 0.066^{e} *
Poly sack-4½ **	13.07±.0.06^{b}	24.4± 0.41^{b}	81.5 ± 0.2^{ab}	76.10 ± 0.3^{a}	57.8 ± 0.7^{a}	2.01 ± 0.03^{bc}	1.99 ± 0.065^{b}
Hermetic-4½	12.60± 0.20^{c}	24.9± 0.23^{ab}	81.8 ± 0.2^{a}	75.60 ± 0.5^{a}	57.1 ± 0.3^{a}	2.11 ± 0.07^{b}	0.99 ± 0.064^{d}
Poly sack- 9 ***	13.30± 0.10^{a}	24.0± 1.00^{b}	80.2 ± 0.2^{c}	74.04 ± 1.0^{b}	51.3 ± 0.8^{b}	1.88 ± 0.06^{c}	2.96 ± 0.067^{a}
HeHermetic- 9	12.93± 0.06^{b}	24.9± 0.15^{ab}	81.3 ± 0.3^{b}	75.54 ± 0.3^{a}	55.6 ± 1.3^{a}	1.95 ± 0.07^{c}	1.45 ± 0.065^{c}
Bg 300							
Initial	12.03± 0.06^{d}	27.8± 0.17^{a}	80.5 ± 0.2^{a}	74.3 ± 0.1^{a}	57.6 ± 0.8^{a}	3.00 ± 0.11^{a}	0.64 ± 0.066^{e}
Poly sack-4½	13.10± 0.17^{b}	26.8± 0.10^{c}	80.1 ± 0.2^{ab}	73.0 ± 0.6^{a}	55.0 ± 1.7^{b}	2.05 ± 0.09^{b}	1.88 ± 0.070^{b}
Hermetic-4½	12.30± 0.10^{c}	27.0± 0.20^{bc}	79.7 ± 0.9^{b}	74.2 ± 0.8^{a}	57.8 ± 0.7^{a}	2.15 ± 0.09^{b}	0.83 ± 0.067^{d}
Poly sack- 9	13.37± 0.06^{a}	27.1± 0.20^{bc}	80.0 ± 0.3^{ab}	70.2 ± 0.7^{b}	51.0 ± 0.2^{c}	1.87 ± 0.03^{c}	3.08 ± 0.066^{a}
Hermetic- 9	12.93± 0.06^{b}	27.2± 0.20^{b}	80.6 ± 0.0^{a}	73.8 ± 1.5^{a}	55.1 ± 0.5^{b}	2.00 ± 0.10^{bc}	1.57 ± 0.067^{c}

Poly sack storage for 4 ½ months   * Poly sack storage for 9 months

* Mean ± SD; Mean values of each variety within a column with different letters are significantly different at $p=0.05$.

MC – Moisture content, TGM- Thousand grain mass, BR- Brown rice percentage, TMR–Total milled rice percentage HRY–Head rice yield percentage, Acid number – FFA exchange with surrounding air. The change in storage temperature and RH was due to the hygroscopic nature of the starch granules (Juliano, 1964). The pattern of moisture increase during storage was similar in both varieties. However, different varieties equilibrate to different moisture contents in a given environmental condition depending on whether the grain is adsorbing or desorbing moisture to the equilibrium state (Kunze and Wratten, 1985; Pearce *et al.*, 2001). These differences in MC between storage methods indicate the importance of having hermetic storage conditions to avoid moisture diffusion into the storage system.

Thousand grain mass

The weight of 1,000 grains differs according to the variety, its origin, etc., (Baumans, 1985). The two varieties had different TGM initially, and decreased their values by the end of 4½ and 9 months in both poly-sack and hermetic conditions (Table 1). The decrease in TGM is the loss in mass of a given variety during storage. A trial conducted with hermetically stored "*Nadu*" type rice in Sri Lanka by Donahaye *et al.* (1991) found that a 0.33 - 0.64 % loss in dry weight due to metabolic activity of rice during 6 months of storage, which was calculated according the TGM loss. Based on TGM, the calculated mass loss of paddy in poly-sacks after 9 months of storage were 4.6 % and 8.0 % for Bg 352 and Bg 300, respectively, where it was 2.2 % and 2.5 %, respectively, in hermetic bags. The decrease in TGM in both varieties during 0 to 4½ storage was greater than 4½ to 9 months of storage. The metabolic activity of live grains might have led to the decrease in TGM while the moisture absorption during storage might have lowered the rate of decrease in TGM. Kunze and Wratten (1985) reported that, there is a positive correlation between TGM and MC of paddy and this may be the reason for the above difference of TGM observed.

Milling parameters

The TMR yield of Bg 352 has improved after 4½ months of storage compared to initial values despite the storage methods (Table 1). The milling quality of just harvested rice is improved by adequate storage and stored grains have greater tensile strength (Kunze and Choudhury, 1972). In contrast, Adikarinayake (2005) found that TMR yield of poly-sack stored paddy of Bg 94-1 for 6 months was not different to initial TMR yield. In the present study, irrespective of the storage method, Bg 300 behaved similarly, showing no significant change in TMR after 4½ months of storage. However, Ben *et al.* (2006) found that four paddy samples stored for 8 months in hermetic IRRI-super bags led to a 2.14 % higher milling recovery and in open-storage it was only 0.76 %. The TMR values of both varieties stored for 9 months in poly-sacks recorded lower values compared to all the other three storage conditions.

Hermetic storage condition has supported to maintain TMR of both varieties till 9 months. Therefore, hermetic storage for 9 months can be recommended to store paddy for better TMR.

Different varieties perform differently in storage and produce different HRY values. There was a significant increase in HRY of Bg 352 with 4½ months storage. However, grains of Bg 300 stored in IRRI-super bag had similar HRY to that of initial value but in poly-sacks it was lower (Table 1). Ben *et al.* (2006) found that after 8 months of storage, HRY in hermetically stored bags decreased by 1.23 %. These results were in contrary to the findings of Adikarinayake (2005) where the HRY percentages of Bg 94-1 and Bg 34-8 were similar to the initial HRY even after 6 months of hermetic storage. Bakker *et al.* (2003) observed no decline in milling recovery and HRY in paddy stored in hermetic storage system. In the present study. there was also no decline in HRY of Bg 352 and Bg 300 at 9 months compared to 4½ months of hermetic storage. This process probably caused moisture stress leading to kernel fissuring and breakage (Donahaye, *et al.*, 2001b).

Grain whiteness

After 4½ months of storage, WH in grains of Bg 352 declined ($p<0.05$) comparative to its initial and there was no difference ($p>0.05$) in WH between two storage methods (Figure 1). In contrast Bg 300 has maintained its initial whiteness till 4½ months when stored in poly-sacks but, WH declined in hermetic storage. However, during 9 months of storage, both varieties have lowered their WH compared to the initial. White colour changed to yellow after a period of storage due to aging of rice and the rate of yellowing is affected by MC, temperature and oxygen content in the stored environment (Wiset, 2005). Having different environments in poly-sack and hermetic storage, the two varieties behaved differently. Hermetic storage condition has adversely affected the WH of Bg 300 during storage as indicated by the drastic decline of WH in 4½ month and the continued until 9 months.

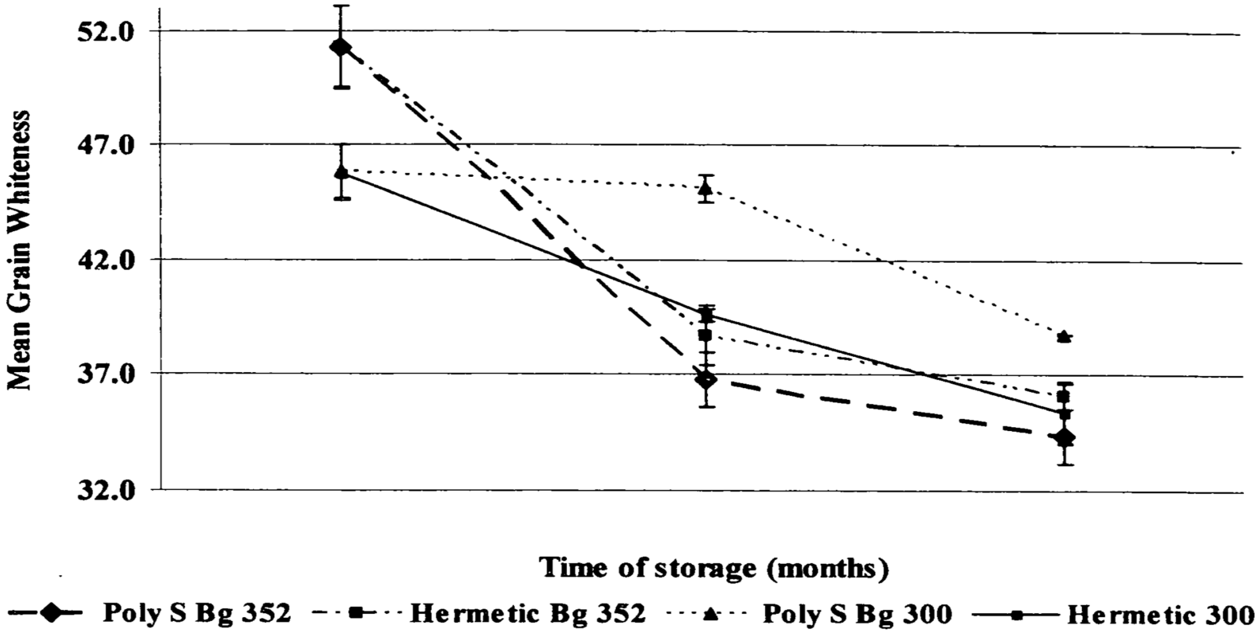

Figure 1. Change in grain whiteness of *Bg* 352 and *Bg* 300 under poly-sack and hermetic storage over time

Crude fat content and free fat acidity (Acid Number)

After 4½ and 9 months of storage, grain crude fat contents have decreased by 17.6 % and 23 % in poly-sacks. In hermetic storage, the reduction was by 13.5 % and 20 % (Table 1). Fats in grains are readily broken down by lipases into free fatty acids and glycerol during storage, particularly when the temperature and moisture contents are high (Pomeranz, 1992). The variation in fat content in storage depends upon the variety, temperature of storage and the duration (Weffen and Zuxun, 2002). Natural fats, which are mixtures of fatty acids and glycerol, are essentially neutral. Unfavorable storage conditions cause partial hydrolysis of glycerides and results the increase of acidity which is an indication of the deterioration of quality (AACC, 2000).

Initial FFA contents of 0.53 ± 0.066 in Bg 352 and 0.64 ± 0.066 in Bg 300 increased gradually with storage. The increase at 4½ and 9 months were grater in poly-sack than in hermetically stored paddy. The decline in fat content was explained by the increase in FFA, which is a product of lipid hydrolysis of fat. The availability of high oxygen and MC in poly-sacks might have led to higher FFA values than that in hermetically stored paddy.

Sensory quality characteristics

The cooking quality of rice depends greatly on the variety and the length of storage. According to Girst (1986) immediately after harvest, cooking quality of all varieties is poor and these characteristics become progressively less pronounced with aging until about 6-12 months. Contrastingly, in this study initially sensory score of Bg 352 and Bg 300 were in the range of "good" (Figure 2) and there was a gradual decline of tenderness/taste. Similarly, Sutprakorn *et al.* (1989) reported that the cooked rice had reduced tenderness as storage period increased and lower scores were obtained with prolong storage. There was no significant difference between two methods of storage in tenderness at 4½ months. However, after 9 months, hermetically stored cooked rice had higher tenderness than that stored in poly-sack bags.

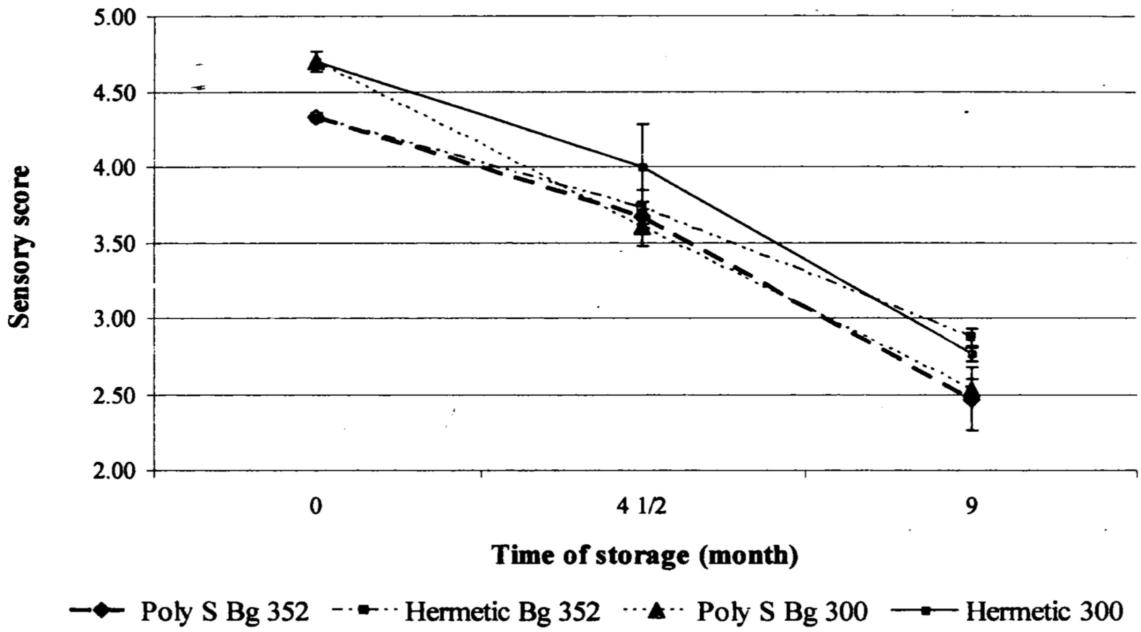

Figure 2. Change in sensory taste score of *Bg* 352 and *Bg* 300 over time under poly-sack and hermetic storage

CONCLUSIONS

Paddy stored under hermetic conditions minimized the increase in moisture content during storage which leads to the reduction in deterioration of quality. Therefore, there was a reduction in the loss of grain mass resulting in a higher TGM in hermetic storage than that of poly-sack storage. Milling attributes were favored by the hermetic storage as grain moisture content was controlled in the hermetic sack. The break down of grain fat was lower in hermetic condition compared to poly-sack storage. Decreased MC and reduction in fat hydrolysis and oxidation in hermetic storage have increased tenderness under hermetic storage. Therefore hermetic storage could be recognized as a better storage method to improve the quality of rice

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the National Science Foundation (NSF), Colombo 7, Sri Lanka for funding the project.

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