Tropical Agricultural Research Vol. 20: 102 - 114 (2008)

Effect of Hermetic-Storage on Milling Characteristics of Six Different Varieties of Paddy

R.F. Hafeel, B.D.R. Prasantha[1] and D.M.N. Dissanayake[2]

Postgraduate Institute of Agriculture
University of Peradeniya
Peradeniya, Sri Lanka

ABSTRACT. *This study was conducted to evaluate the hermetic and common storage systems on the milling quality of six varieties of paddy, Bg 352, Bg 300, Bg 358, Bg 360, At 405 and At 306. Paddies were first solar dried to moisture content of 12±1% (wb) and then disinfested with chloroform before storage. The six varieties were stored in hermetic IRRI-super bags and common poly-sack bags at an air temperate of 30±5 °C and a relative humidity of 80±5%. After 4½ months of storage, samples were tested for gas content, moisture content (MC), thousand grain mass (TGM), grain hardness, grain dimensions, whiteness (WH), milling parameters, and true density (D_T) with their initial condition. Oxygen content dropped to 13.7% within 4 ½ months and carbon dioxide rose to 2.4% in the hermetic IRRI-super bag. The results showed that MC of the poly-sack stored paddy (13-13.6%) significantly increased ($p<0.05$) compared to the MC of IRRI-super bag stored paddy (12.3-12.6%). A significant decrease ($p<0.05$) in thousand grain mass (TGM) and true density was also observed in poly-sack stored paddy. During 4½ months of storage of paddy in poly-sack and IRRI-super bags, reduction of TGM by 7.7 and 3.8% were observed respectively. Whereas, D_T was 1.17 g/cm^3 for poly-sack and 1.2 g/cm^3 for IRRI-super bag stored paddy, no significant change ($p>0.05$) was found in milling parameters and other properties among two storage methods. However, different quality parameters were observed according to the varietal differences under all test conditions. The results of this study suggest that hermetic storage of dried paddy has no adverse effect on milling yield, grain whiteness and other quality parameters up to 4 ½ months of storage.*

INTRODUCTION

Nearly 40-50% of the paddy harvested in Sri Lanka is kept by farmers for consumption, as seed paddy and for future sale for a period of six to twelve months (Adhikarinayake, 2005). Farm storage provides about 70% of the total food requirements of the farm family and it is a substantial contribution to the farm income during the off-season (Palipane, 2000; Adhikarinayake, 2005). Today, paddy is commonly stored in poly-sack bags than gunny bags but to a limited extent, stored in traditional storage. 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, 1991). Insect infestation causes significant damage to quality of paddy during storage (Trematerra *et al.,* 2004) and tends to speed up the undesirable

[1] Department of Food Science & Technology, Faculty of Agriculture, University of Peradeniya.

[2] Rice Research and Development Institute, Department of Agriculture, Batalagoda.

chemical changes among stored grains and their products (Smith *et al*., 1971; Raj and Singaravadivel, 1990; Seitz and Sauer, 1996). Therefore, deterioration of quality of paddy/rice is unavoidable under common storage systems.

Hermetic storage system generally is considered as a promising alternative method 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 at tropical outdoors in Sri Lanka using hermetically sealed plastic liners. In hermetic storage, the atmosphere is been modified by sealing the container hermitically, so that a gas composition of low oxygen and high carbon dioxide atmosphere can be obtained after few weeks of storage (Busta *et al.,* 1980). The alteration of the stored atmosphere gas composition is achieved through the respiration metabolism of the grain, insects and fungi present in the stored grain. Therefore, insects enclosed in the stored grain die due to lack of oxygen and high carbon dioxide developed inside the hermetic storage system (Emekcl *et al.,* 2001) as well as inhibit the growth of fungi, which may produce aflatoxins (Hocking, 1990; Richard-Molard *et al.,* 1980; Caliboso and Sabio, 1999). Prior studies have shown that losses are less when paddy/rice is stored hermetically but few studies have been carried out to evaluate the relationship between paddy/rice hermetic storage and changes in their quality parameters (Gras and Bason, 1990; Ben *et al.,* 2006).

There is an increasing demand for quality rice in the national and international markets today. In order to fullfill the market demand on quality rice, a thorough investigation should be done under same uninfected conditions of hermetic system. Furthermore, quality changes due to these practices are not yet studied under local conditions. Therefore, the objective of this study was to investigate the effects of hermetic storage in the IRRI-super-bag and compare it with common poly-sack bag storage in terms of milling quality of six different paddy varieties stored for 4½ months. In this experiment, insects were controlled by hermetic storage condition, but infestation of insects was externally controlled when the grains were stored in poly sack bags.

MATERIALS AND METHODS

Sample preparation

High yielding six paddy varieties with three grain types were obtained from Rice Research and Development Institute (RRDI), Batalagoda for the experiment (Table 1).

Table 1. Paddy varieties according to their grain type and maturity

Paddy variety	Grain type	Common rice name	Maturity stage (days)
Bg 352	Intermediate bold	*Nadu*	105
Bg 300	Intermediate bold	*Nadu*	90
Bg 358	Short round	*Samba*	105
Bg 360	Short round	*Samba*	105
At 405	Long slender	*Basmati*	120
At 306	Long slender	*Basmati*	90

Paddy was harvested at physiological maturity which has been defined by RRDI. Before storage, paddy samples were sun dried, without exposure to high temperature, to 12±1%

moisture content (wet basis) on a smooth drying floor. Paddy samples were cleaned and disinfested by using chloroform ($CHCl_3$) vapor in a gastight chamber prior to storage and initial testing.

Storage parameters

A sample of 2 kg of paddy from each paddy variety was stored under two different types of storage conditions, "Poly-sack" (polypropylene having strength of *Danier* 1850) bags as the control and IRRI-super-bags for hermetically sealed storage. IRRI-super bags were obtained from International Rice Research Institute (IRRI), Philippines, which are highly impermeable to air (Oxygen 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 samples were stored in an empty warehouse, where the average air temperature was 30±5 °C and the air relative humidity (RH) was 80±5%. Warehouse was cleaned and disinfested from insects before starting the storage trial. Generally, paddy grains change their physicochemical properties within first 3-4 months of storage soon after harvest (Villareal *et al*., 1976). Therefore, samples were tested initially (before storage) and 4½ months after storage in poly-sack bags and hermetically sealed IRRI-super bags.

Hermetic condition

To evaluate the hermetically sealed condition built up in the IRRI-super bag, the oxygen (O_2) and carbon dioxide (CO_2) concentrations were monitored using a gas analyzer (model: ICA 15 Dual Analyzer). Ambient temperature and RH in the samples were monitored using a data logger (model: TC PicoTech) with thermocouples and RH probes (model: TC PicoTech).

Moisture content

The moisture content (MC) of the samples was determined via an oven calibrated digital grain moisture meter (model: GMK 303). Initial MC and MC of stored paddy (4 ½ months) samples were also recorded at the end of storage period.

Thousand grain mass

The 1000 kernels from each paddy variety and storage type were counted using digital grain counter (model: 6708-Indosaw) in triplicate and weighed separately to determine 1000 kernel weight in grams (g) to evaluate the thousand grain mass (TGM).

Grain hardness

Ten undamaged paddy kernels without cracks and splits were selected by using grain scope (model: TX 200-KETT). The selected kernels were carefully placed in the hardness tester (model: Stake 174886) to measure the grain hardness. Force at first rupture was considered as the yield point.

Milling parameters

A pre-cleaned paddy sample weighing 150 g was passed twice through a laboratory rubber roll sheller (model: Satake) for dehusking. The weight of the dehusked brown rice was recorded. The resulting brown rice sample was then polished for 1 minute by using an abrasive type polisher (model: 2 TX McGill) to obtain a typical degree of polish of ca. 8%. Total milled rice was passed through a sieve to remove broken grains and further separation was done manually. However, milled rice kernels that are at least two-third of the original kernel length was considered as head rice. Percentage of brown rice (BR) was calculated after dehusking and percentage of total milled rice (TMR) was calculated after polishing to the weight of unmilled paddy. Head rice yield (HRY) was expressed as the percentage ratio of the weight of unbroken kernel to the weight of unmilled paddy.

Grain whiteness

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

Grain dimensions

A total of 50 paddy grains were randomly picked from each sample and hand-dehulled with tweezers. The length (L, major axis) and width (W, intermediate axis) of brown rice kernels were measured using a micrometer screw gauge with an accuracy of 0.001 mm. Paddy samples were classified according to the IRRI size and shape classification of rice (Cruz and Kush, 2000).

True density

The true density (D_T) of paddy samples was determined by the kerosene displacement method (Bhattacharya *et al*., 1972). An empty specific gravity bottle having a capacity of 50 ml was weighed. It was first filled with kerosene to get the weight. Then 15 g of paddy was poured into the bottle and it was carefully filled with kerosene. The final weight was measured after cleaning the surface of the bottle.

Statistical design

A two factor factorial (6 paddy varieties x 2 storage methods) experimental design was used in this experiment. The ANOVA was performed in a completely randomized manner (CRD). All experiments had at least three replications of each measurement. The SAS (SAS institute Inc., Cary, NC, USA) was used for statistical analysis. Duncan's multiple range test was used to estimate significant differences among the means at the 5% probability level.

RESULTS AND DISCUSSION

Hermetic condition

According to the reading, average temperature within the samples of hermetic IRRI-super bags was 30±2.5 ºC. Recording of inter granular air RH was 70±2% of the same samples. Temperature and RH within the poly-sack (control) were more or less close to ambient condition which was 32±3 ˚C and 80±5% respectively. The O_2 level dropped to 13.7% in hermetic storage within 4½ months of storage coupled with an increase in CO_2 content to 2.4%. Previous studies have shown that the level of CO_2 content rise above 12% within 3-4 weeks of hermetic storage of paddy (Caliboso and Sabio, 1998, Donahaye, *et al*., 2001, Ferizli *et al*., 2001) with artificial infestation of some stored pests. For this study, infestation of insects was effectively controlled by various means such as fumigation, sanitation, cleaning etc. Therefore, depletion of O_2 level of this hermitic system remained low due to respiration of paddy. The level of CO_2 generated was also lower in paddy with lower MC < 14% and higher with higher MC > 14% (Caliboso and Sabio, 1998).

Moisture content

Before storage, initial MC of *Bg* 352*,* *Bg* 300, *Bg* 358 and *Bg* 360 paddy was ranging from 12 to 12.5%. After 4½ months of storage, MC of poly-sack bag stored paddy increased from 13 to 13.6% and there was only a slight increase in MC from 12.3 to 12.6% in hermetically sealed IRRI-super bags (Figure 1A). Therefore, the MC of initial samples and two storage conditions were significantly different ($p<0.05$) after 4½ months of storage. These results are consistent with the finding of Ben *et al.* (2006), who reported that the increase of moisture in IRRI-super bags was probably due to the respiration of grains. Poly-sack stored paddy had increased moisture through moisture exchange with surrounding air while increases with a change in storage temperature or RH due to hygroscopic nature of the starch granules (Juliano, 1964) which may be directly related to the amylase content and protein (Zhou *et al*., 2002). Contrasting to the above findings, Kyu *et al.* (1999) reported that, paddy stored for four years did not increase its moisture during storage. However, different varieties equilibrate to different moisture contents in a given environment 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 indicate the importance of having hermetic storage condition to avoid moisture diffusion into the storage system.

Thousand grain mass

During 4½ months of storage TGM has decreased significantly ($p<0.05$) compared to the initial value (Figure 1B). However, hermetically stored paddy in IRRI-super bag showed significantly higher ($p<0.05$) TGM than poly-sack stored paddy. All six varieties showed significant difference ($p<0.05$) in their TGM, the highest TGM was found in "Nadu" *Bg* 300 (27.8 g) and *Bg* 352 (26.1 g) while "Samba" varieties of *Bg* 358 (16.7 g) and *Bg* 360 (14 g) showed the lowest TGM. The weight of 1,000 kernels differs according to the variety, origin, etc., (Baumans 1985).

According to the mass loss calculated based on TGM method in this study were 3.8 and 7.7% in hermetic IRRI-super bag and conventional poly-sack bag storage respectively. A trial conducted with hermetically stored "*Nadu"* type rice in Sri Lanka by Donahaye *et al.* (1991) found that 0.33 - 0.64% loss in dry weight due to metabolic activity of rice during 6 months of storage which was calculated according to the method of total mass change which is related to the TGM change. Kunze and Wratten (1985) reported that, there was positive correlation between TGM and MC of paddy and this may be the reason for the change of TGM ($p<0.05$) observed for two storage systems.

Hardness

During 4½ months of storage, hardness of paddy varieties increased significantly ($p<0.05$) than initial condition but the values were almost similar ($p>0.05$) for two storage methods (Figure 1). The hardness value for the IRRI-super bag stored paddy varieties was ranging from 40-72 N, where as it was ranging from 32 -72 N for the poly-sack bags stored paddies. However, coefficient of variations (CV=SD/mean x100) of samples stored in both IRRI-super bag and poly-sack bag have CV of 25.5 and 33% respectively. Therefore, hardness of paddy stored in IRRI-super bags may be higher than that of paddy stored in poly-sack bags. Nagoto, *et al.* (1964) reported that the hardness at any specified point within the endosperm, increases or decreases linearly according to the decrease or increase of its moisture content. Paddy variety *At* 306 recorded the highest increase in MC compared to other varieties as well as the highest hardness values, while *Bg* 358 had the lowest hardness. Although paddy/rice hardness increases during storage with time, hardness may reach a maximum and then decline (Perez and Juliano, 1981).

Brown rice percentage

Varieties presented different BR% initially and after 4½ months of storage (Table 2), it was found that the BR% of IRRI-super bag stored paddy varieties were not significantly different ($p>0.05$) form the BR yields of the poly-sack bag stored paddy. With storage time, there will be an improvement in BR% due to decaying of hull compared to brown rice in any of the storage conditions. However decaying rate can be greatly controlled by storing the paddy in a hermetic storage system (Donahaye, *et al*., 2001a).

Total milled rice percentage

The TMR yield of paddy varieties stored in hermetic IRRI-super bag and poly-sack bag did not change significantly ($p>0.05$) after 4½ months of storage. However, average TMR recovery was about 74% for *Bg* 352, *Bg* 300 and *Bg* 358 which was significantly higher ($p<0.05$) than *At* 405 (72%) and *At* 306 (68%) (Table 2).

After 4 ½ months of storage, TMR recovery in both poly-sack bag and IRRI-super bag stored paddy samples increased by an average of 1.5% compared to the initial samples. The milling quality of freshly harvested rice is improved by adequate storage and stored grains have greater tensile strength (Kunze and Choudhury, 1972) which is reflected in greater resistance to milling and milling breakage. Contrasting to this study, Adikarinayake (2005) found that TMR yield of the airtight and poly-sack storage paddy (*Bg* 94-1) had no difference with initial TMR yield after 6 months of storage. However, Ben *et al*, (2006) found that four paddy samples stored in hermetic IRRI-super bag led to 2.14% higher milling recovery than in open-storage samples and only 0.76% lower milling recovery than initial samples after 8 months of storage.

Head rice yield percentage

The results of HRY of the different paddy varieties vs. tested storage conditions are shown in Table 2. Initial values of HRY was significantly higher ($p<0.05$) than two storage methods. It was found that paddy varieties stored in IRRI-super bag and poly-sack bag had decreased their average HRY by 3.5% and 4.2% compared to initial condition respectively. Similar to these findings, Ben *et al.* (2006) found that only 1.23% lower HRY in hermetically stored (similar storage system) paddy for 8 months than initial. These results were contrasting to the findings of Adikarinayake (2005) where the HRY percentages of *Bg* 94-1 and *Bg* 34-8 were similar to the initial HRY percentages after 6 months of hermetic storage. According to Bakker *et al*. (2003), there was no decline in milling recovery and HRY in paddy stored in hermetic storage system. This condition could be brought by grain conditioning which includes absorption of moisture during storage. This process probably caused moisture stress leading to kernel fissuring and breakage (Donahaye, *et al*., 2001b).

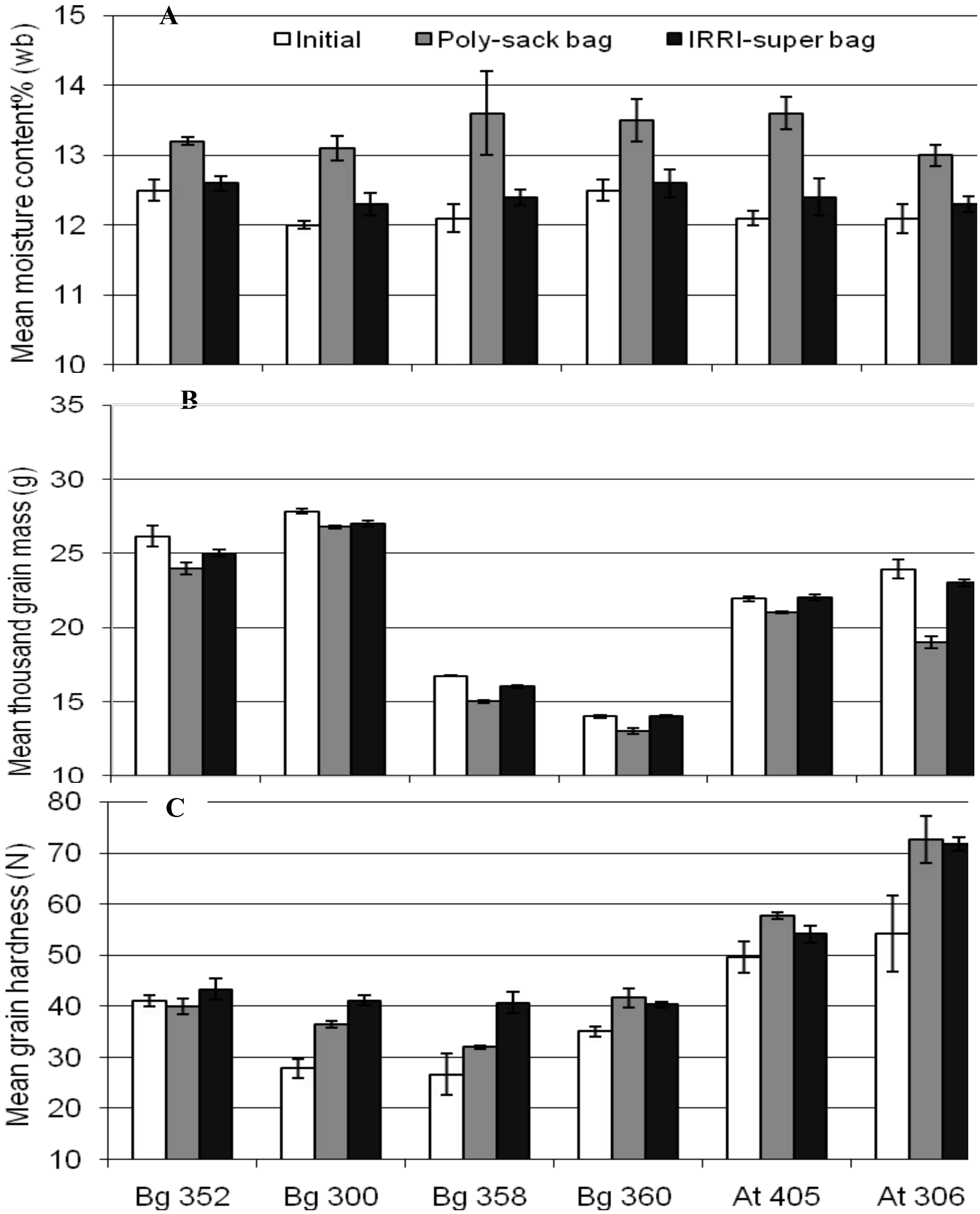

Figure 1. Effect of 4 ½ months storage of six paddy varieties on (A) moisture content (wet basis, %), (B) thousand grain mass (g) and (C) Grain hardness (N)

Table 2. Grain quality parameters of six paddy varieties initially and after 4½ months of storage.

Storage	BR %*\	TMR %*	HRY %*	WH %*	Length* (mm)	Width* (mm)	D_T * (x 1000 kg/m^3)
Bg 352							
Initial	78.7 ± 0.4^{b}	71.3 ± 0.1^{b}	50.0 ± 1.2^{b}	51.3 ± 1.8^{a}	5.4 ± 0.06^{a}	2.5 ± 0.03^{a}	1.20 ± 0.01^{a}
Poly sack	81.5 ± 0.2^{a}	76.1 ± 0.3^{a}	57.8 ± 0.7^{a}	36.8 ± 1.2^{b}	5.3 ± 0.04^{a}	2.5 ± 0.14^{a}	1.20 ± 0.01^{b}
Hermetic	81.8 ± 0.2^{a}	75.6 ± 0.5^{a}	57.5 ± 0.3^{a}	38.7 ± 1.7^{b}	5.3 ± 0.05^{a}	2.4 ± 0.14^{a}	1.2 1± 0.01^{b}
Bg 300							
Initial	80.5 ± 0.2^{a}	74.3 ± 0.1^{a}	57.6 ± 0.8^{ab}	45.8 ± 1.2^{a}	5.5 ± 0.01^{a}	2.5 ± 0.03^{a}	1.24 ± 0.01^{a}
Poly sack	80.1 ± 0.2^{a}	73.0 ± 0.6^{a}	55.0 ± 1.7^{b}	45.1 ± 0.8^{a}	5.5 ± 0.02^{a}	2.4 ± 0.03^{a}	1.22± 0.01^{a}
Hermetic	79.7 ± 0.9^{a}	74.2 ± 0.8^{a}	57.8 ± 0.7^{a}	39.7± 0.3^{b}	5.5 ± 0.02^{a}	2.5 ± 0.02^{a}	1.23± 0.01^{a}
Bg 358							
Initial	78.6 ± 0.1^{b}	73.7 ± 0.6^{b}	59.0 ± 1.4^{a}	40.7 ± 2.3^{a}	3.9 ± 0.06^{a}	2.5 ± 0.02^{a}	1.25 ± 0.01^{a}
Poly sack	78.5 ± 0.6^{b}	73.1 ± 1.0^{b}	60.8 ± 0.4^{a}	34.2 ± 0.5^{b}	3.8 ± 0.07^{a}	2.5 ± 0.02^{a}	1.19 ± 0.01^{a}
Hermetic	79.8 ± 0.2^{a}	75.2 ± 0.4^{a}	60.7 ± 0.5^{a}	32.7 ± 0.8^{b}	3.9 ± 0.03^{a}	2.4 ± 0.01^{a}	1.21± 0.01^{b}
Bg 360							
Initial	76.6 ± 0.1^{b}	70.7 ± 0.2^{a}	57.9 ± 0.2^{a}	44.2 ± 1.3^{a}	4.0 ± 0.06^{a}	2.1 ± 0.02^{a}	1.23 ± 0.00^{a}
Poly sack	78.2 ± 0.5^{a}	72.5 ± 0.6^{a}	59.6 ± 0.4^{a}	35.7 ± 2.5^{c}	4.0 ± 0.06^{a}	2.0 ± 0.03^{a}	1.15 ± 0.01^{b}
Hermetic	78.1 ± 0.2^{ab}	72.3 ± 0.7^{a}	59.3 ± 0.4^{a}	38.6 ± 0.4^{b}	4.1 ± 0.04^{a}	1.83± 0.02^{b}	1.20 ± 0.01^{c}
At 405							
Initial	79.4 ± 0.1^{a}	72.5 ± 0.4^{a}	53.5 ± 1.4^{a}	39.7 ± 2.6^{a}	7.1 ± 0.04^{a}	2.0 ± 0.02^{a}	1.19 ± 0.01^{a}
Poly sack	79.5 ± 0.2^{a}	72.0 ± 0.7^{a}	48.3 ± 0.6^{b}	40.3 ± 0.3^{a}	7.0 ± 0.02^{a}	1.8 ± 0.01^{a}	1.18 ± 0.01^{a}
Hermetic	79.1 ± 0.3^{a}	71.3 ± 0.9^{a}	47.0 ± 1.2^{b}	41.2 ± 1.8^{a}	7.1 ± 0.02^{a}	1.9 ± 0.01^{a}	1.18 ± 0.01^{a}
At 306							
Initial	77.7 ± 0.6^{a}	68.4 ± 0.4^{a}	41.3 ± 2.6^{a}	45.6 ± 1.7^{a}	7.4 ± 0.04^{a}	1.8 ± 0.01^{a}	1.20 ± 0.01^{a}
Poly sack	75.9 ± 2.1^{a}	68.3 ± 2.2^{a}	24.7 ± 0.2^{b}	39.7 ± 0.9^{b}	7.4 ± 0.02^{a}	1.8 ± 0.07^{a}	1.13 ± 0.02^{b}
Hermetic	77.2 ± 0.8^{a}	68.7 ± 0.6^{a}	25.3 ± 1.5^{b}	40.5 ± 0.7^{b}	7.3 ± 0.20^{a}	1.9 ± 0.06^{a}	1.17 ± 0.01^{a}

*Mean ± SD; Mean values of each variety within a column with different superscripts are significantly different at (*P=0.05*)
BR – Brown rice %   TMR – Total milled rice %   HRY – Head rice yield %   WH – Grain whiteness D_T – Paddy true density

Whiteness of rice

The degree of grain WH for initial and two storage methods are listed in Table 2. After 4½ months storage, paddy samples had lowered grain WH value ($p<0.05$) but there was no difference ($p>0.05$) between two storage methods. Hermetically stored paddy yielded milled rice was slightly yellowish in color than initial samples where average WH for two stored methods was 38.5 and 44.5 respectively. The white color becomes yellow after a period of storage due to aging of rice. It was found that the rate of yellowing is affected by MC, temperature and oxygen content in the stored environment (Wiset, 2005). Paddy samples stored in IRRI-super bags have decreased ($p<0.05$) the WH by about 13.4% than initial sample value. Irrespective of the storage method, *Bg* 358 showed the lowest mean whiteness and *Bg* 300 showed highest mean whiteness value. So *et al.* (2000) indicated that the color of rice became darker gray than initial rice where "L" value was decreased from 64.2 to 61.6 after 4 years of storage.

According to Weffen and Zuxun (2002), vacuum packed rice has given strong rancid odor and discoloration after 2 years of storage. This change in color could be due to the non-enzymatic browning and/or the diffusion of coloring pigments of the hull and barn to the endosperm during storage (Reyes and Jindal, 1989).

Grain dimensions

There were no significant differences ($p>0.05$) in the brown rice dimension among two tested storage conditions and initial values (Table 2). Moisture content of the paddy samples stored in poly-sack bag had increased from 12 to 13.6% ($p<0.05$) during storage, but there was no significant influence on grain dimension. Grain dimensions may apparently be limited by the morphological structure of the grain and the grain length acts as an independent variable which is not related to any other parameter. However, Kunze and Wratten (1985) reported that the grain expands in all three dimensions as MC content increases. According to Bhattacharya *et al*. (1972), as the MC increased from about 13 to 27%, L and W increased from 5.9 to 6.2 mm and 2.26 to 2.4 mm respectively but L/W ratio remained unchanged.

True density

Initial average value of all paddy varieties, in true density (1200 kg/m^3) was significantly higher ($p<0.05$) than two storage methods. Average value of true density (for all varieties) at IRRI-bag stored paddy was 1200 kg/m^3 and it was 1170 kg/m^3 in poly-sack bag stored paddy ($p<0.05$) after 4 ½ months (Table 2). *At* 306 being a long slender variety had the lowest density values than other varieties and it had the lowest rate of increase of moisture during hermetic storage in IRRI-super bag. Bhattacharya *et al*. (1972) reported that, for every 1% increase in MC, the density of the paddy increased by about 7.5 kg/m^3. This increase due to presence of air space between the kernel and the husk, enable the kernel to hydrate without affecting the paddy kernel volume.

CONCLUSIONS

Regardless of the storage method, duration of 4 ½ months storage has significant effect on the physical and milling qualities of paddy such as MC % (wb), milling yield, TGM, whiteness hardness and density. The MC of hermetically stored paddy had been slightly increased compared to the MC of poly-sack bag stored paddy. The MC of poly-sack stored paddy varieties had increased considerably with the change of ambient conditions such as temperature and RH. The other important parameters were TGM and true density which indicates the weight loss and compactness of the grain. Those were minimally changed in the paddies stored hermetically in IRRI-super bag than conventional poly-sack storage. The other milling and physical parameters did not show significant differences among two storage methods. However, different varieties behaved differently for each parameter under two storage conditions. On the average, *Nadu* and *Samba* varieties showed better milling qualities and higher true densities than *Basmati*. Therefore, hermetic storage system can be a safe and viable alternative to conventional bag system for storage of paddy. They are capable of preserving the quality of dry paddy while minimizing the weight loss.

ACKNOWLEDGEMENTS

This research was funded by the National Science Foundation (NSF), Colombo 07, Sri Lanka. The authors wish to express their appreciation to the NSF, Faculty of Agriculture, University of Peradeniya and Department of Agriculture for their valuable support for this research.

REFERENCES

Adikarinayake, T.B. (2005). Methodical design to improve income of paddy farmers in Sri Lanka. Ph.D. thesis, Univ. Wageningen.

Anonymous (2005). Super bags. Rice Today. IRRI 4(1): 52.

Bakker, R.R., Rickman, J.F. and Kim, O.W. (2003). Rice quality management through better drying, storage and milling practices. pp 687-697. In: Mew, T. W., Brar, D.S., Dave, D. and Hardy, B. (Eds.). Rice science innovations and impact for livelihood. Proc. of the Int. Rice Res. Conf. 16-19 September 2002. Beijing, China.

Baumans, G. (1985). Grain handling and storage. Development in Agric. Eng. 4, Elsevior Publishers B.V. New York.

Ben, D.C., Liem, P.V., Dao, N.T., Gummert, M. and J.F. Rickman. (2006). Effect of hermetic storage in the super bag on seed quality and milled rice quality of different varieties in Bac Lieu. Vietnam. Agric. Eng. 31(2): 55-56.

Bhattacharya, K.R., Sowbhagya, C.M. and Indudhara swamy Y.M. 1972. Some physical properties of paddy and their interrelation. J. Sci. Fd. Agric. 23: 171-186.

Busta, F.F., Smith, L.B. and Christensen, C.M. (1980). Microbiology of controlled atmosphere storage-An overview. pp 121-132. In: Shejbal, J. (Ed.). Controlled atmosphere storage of grains. Int. Sym.. held from 12-15 May 1980 at Rome-Italy. Development in Agric. Engi 1. Elsevior, New York.

Caliboso, F.M. and Sabio, G.C. (1998). Hermetic storage of grains in the tropics. pp. 59-72. In: Nawa, Y., Takagi, H. and Oguchi, A. (Eds). Post harvest technology in Asia: A step forward a stable supply of food products. The 5th JIRCAS Int. Sym. held 9-10 September at Japan 1998.

Cruz, N. D. and Kush, G.S. (2000). Rice grain quality evaluation procedures in Aromatic rices. IRRI, Phillippines.

De-Lima, C.P.F. (1990). Airtight storage: principle and practice. pp. 9-19. In: Calderon, M. and Barkai-Golden, R. (Eds). Fd. Pres. Modi. Atm. CRC Press, USA.

Donahaye, E., Navarro, S., Ziv, A., Blauschild, Y. and Weerasinghe, D. (1991). Storage of paddy hermetically sealed plastic liners in Sri Lanka. Trop. Sci. 31: 109-124

Donahaye, J.E., Navarro, S., Andales, S., Mundo, D.A.M., Caliboso, F., Sabio, G., Felix, A., Rindner, M., Azrieli, A. and Dias, R. (2001a). Quality preservation of moist paddy under hermetic conditions. pp. 209-225. In: Donahaye, E.J., Navarro, S. and Leesch, J.G. (Eds). Proc. Int. Conf. of Cont. Atm. and Fum. in Sto. Prod. Executive printing services, Clovis, CA, USA.

Donahaye, J.E., Navarro, S., Sabio, G., Rindner, M., Azriell, A. and Dias, R. (2001b). Reflective covers to prevent condensation in sealed storage in the tropics. pp 227-230. In: Donahaye, J.E., Navarro, S., Leesch, J.G (Eds). Proc. Int. Conf. Cont. Atm. and Fumigation in Stored Products. Fresno, CA, USA.

Emekcl, M., Navarro, S., Donahaye, J.E. and Azriell, A. (2001). Respiration of stored product pest in hermetic conditions. pp 26-35. In: Donahaye, J.E., Navarro, S., Leesch, J.G (Eds). Proc. Int. Conf. Cont. Atm. and Fumi in Std. Prod. Fresno, CA, USA.

Ferizli, A.G, Navarro, S., Donahaye, J.E, Rindner, M. and Azriel, A. (2001). Airtight granary for use by subsistence farmers. pp. 37-43. In: Dhnahaye, E.J., Navarro, S. and Leesch, J.G. (Eds). Proc. Int Conf. of Cont. Atm. and Fumi. in Sto. Prod. Executive printing services, USA.

Fernando, M.D., Palipane, K.B. and Adikarinayake, T.B. (1985). Improvement of farm level grain storage methods. J. Post. Harv. Tech. 1(1): 47-67.

Gras, P.W. and Bason, M.L. (1990). Biochemical Effects of storage atmospheres on grain and grain quality. pp. 70-82. In: Champ, B.R., Highley, E. and Banks, H.J. (Ed.). Fumigation and controlled atmosphere storage of grain. Proc. Int. Conf. held in Singapore, 14-18 February 1989. ACIAR proc No.25.

Hocking, A.D., (1990). Responses of fungi to modified atmospheres. pp. 70-82. In: Champ, B.R., Highley, E. and Banks, H.J. (Eds). Fumigation and controlled atmosphere storage of grain. Proc. Int. Conf. held in Singapore, 14-18 February 1989. ACIAR Proc. No.25.

Juliano, B.O. 1964. Hygroscopic equilibria of rough rice. Ce. Chem. 41:191-197

Kunze O.R., and Chaudhury, M.S.U. (1972). Moisture adsorbtion related to the tensile strength of rice. Cereal. Chem. 49: 684-696

Kunze O.R., and Wratten, F.T. (1985). Physical and mechanical properties of rice. pp. 207-231. In: Juliano, B. O. (Ed.). Rice chemistry and technology. AACC, USA.

Kyu, H.S., Young, S.K., Jae, S.H., Ju, Y.J. and Jae M.C. (1999). Studies on the change of components with long–term storage of paddy. Korean J. Food and Nutr. 12(4): 409-414

Nagato, K., Ebat, M. and Ishikawa, M. (1964). On the formation cracks in rice kernels during wetting and drying of paddies. Nippon Sakumotsu Gakki KIji. 33: 82-89

Palipane, K.B. (2000). Current storage practices and quality improvement of stored grains. pp. 13-17. In: SLAAS (Ed.). Seminar on naval strategies in post management of stored grains in developing countries, Colombo, Sri Lanka.

Pearce, M.D., Marks, B.P. and Meullenet, J. F. (2001). Effect of post harvest parameters on functional changes during rough rice storage. Cereal Chem. 78(3): 354-357

Perez, C.M. and Juliano, B.O. (1981). Texture changes and storage rice. J. Text. Stud. 12: 321-333.

Raj, S.A. and Singaravadivel, K. (1990). Biodeterioration in rice (*Oryza sativa* L.) due to low, medium and high moisture. Int. Biodet. 27(3): 237-248

Reyes,V.G.J. and Jindal, V.K. (1989) Conduction heating of high moisture rough rice III. Changes in milling and cooking qualities. J. Fd. Pro. Eng. 11(2):103-115.

Richard-Molard, D., Cahagier, B. and Poisson, J. (1980). Wet grains storage under modified atmospheres. Microbiological aspects. pp 121-132. In: Shejbal, J. (Eds). Controlled atmosphere storage of grains. An Int. Symp. held from 12-15 May 1980 at Rome-Italy. Dvpt. Agric. Engi. 1. Elsevier, New York.

Sartaj, I.Z.. and Ekanayake, S. (1991). Postharvest losses, Tropical Agricultural Research, 3: 115-132.

Seitz, L.M. and Sauer, D.B. (1996). Volatile compounds and odors in grain sorghum infested with common storage insects. Cereal. Chem. 73: 744-750.

Smith, L.W., Pratt, J.J., Nil, I. and Umina, A.P. (1971). Baking and taste properties of bread made from hard wheat flour infested with species of *Tribolium, Tenebrio, Trogoderma* and *Oryzaephilus.* J. Sto. Prod. Res. 6: 307-316.

So, K.H., Kim, Y.S., Hong, J.S.,Jeong, J. Y. and Cho, C. M. (2000). Characteristics of the rice quality with long –term storage of paddy. Korean J. Food and Nuts. 13(1): 21-27

Trematerra, P., Sciarrette, A, Paula, M.C.de, and Lazzari, S.M. (2004). Insect pests infesting a paddy rice storage facility in Brazil: phenology and spatial distribution. *Tecnica Molitoria.* 55(3/A): 103-110.

Villareal, R.M., Resurreccion, A.P., Suzuki, L.P. and Juliano, B.O. (1976). Changes in physicochemical properties of rice during storage. Starch. 28:88-94.

Weffen, Q. and Zuxun., J. (2002). Paddy and rice storage in China. Advances in stored product protection. pp. 26-39. In: Credland, R.F., Armitage, T.M., Bell, C.H. and Highley, G. (Ed.). Proc. 8th Int. Working Conf. Sto. Prod. Prot. CABI publishers, UK.

Wiset, L. (2005). Physical and pasting properties of brown rice starch during storage. pp. 235-238. In: Starch update 2005. Proc. 3rd Conf. Starch Tech. November 4-5, 2005. Queen Sirikit National Convention Centre Bangkok Thailand.

Zhou, Z., Robards, K., Helliwell, S. and Blanchard, C. (2002). Ageing of stored rice: changes in chemical and physical attributes. J. Ce. Sci. 35: 65-78.