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EFFECT ON GERMINATION AND MILLING QUALITY OF PADDY RICE STORED BY VARIOUS HERMETIC OPTIONS

C Cabardo*, E Secretario and M Gummert

Postharvest Unit, International Rice Research Institute
DAPO Box 7777, Metro Manila, Philippines
*Corresponding author's e-mail: *c.cabardo@irri.org*

ABSTRACT

Hermetic storage involves storing crops in a low-oxygen, high-carbon-dioxide atmosphere modified through the respiration of the crop, insects or fungi. In recent years, a number of 50-kg capacity hermetic storage bags have been released in the market as well as locally produced hermetic containers. It has become a problem to distinguish which of these are hermetic and which are not.

The study was conducted to evaluate the effect of various hermetic storage options on the germination and milling characteristics of paddy rice. Hermetic storage options evaluated were five types of hermetic bags: the IRRI Super Bag, GrainPro SGB IIZ, Kantong Semar, Pioneer and Purdue Improved Cowpea Storage (PICS) Bag. Small metal silos were also evaluated.

Paddy rice was dried at 43°C using a recirculating dryer and then stored using the various hermetic storage options. Paddy rice stored in ordinary woven sacks served as the control. Oxygen content and carbon dioxide content inside the containers were monitored weekly. Samples were taken after 3 and 6 months of storage and tested for moisture content (m.c.), germination, insect count, discoloration, milling recovery, head rice recovery and whiteness. Results showed that various hermetic options had different effects on the germination and milling quality of paddy rice. This means that, based on the parameters tested, some options exhibited hermetic characteristics while some did not.

Key Words: paddy rice, hermetic storage, moisture content, germination, live insect count, discoloration, milling recovery, head rice recovery, whiteness

INTRODUCTION

From pre-Neolithic times, people in the Middle East and Europe have kept grain in holes dug in the ground as a form of airtight storage (Hall et al., 1956; Sigaut, 1980). In recent years, airtight storage has been developed both to control insects in dry grain and to prevent mold growth in high-moisture grain (Hyde and Burrell, 1982). Airtight or hermetic storage (HS) 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 (Villers et al., 2008). Controlling the moisture content and insect growth in stored paddy rice maintains high germination in seeds and high milling recovery and head rice recovery in milled rice (Gummert et al., 2006).

Recent technological advances in plastic manufacturing have led to the development of large commercial PVC liners with airtight seals that provide the required durability for climate and gas permeability, and the physical properties to enable HS for extended periods of time (Rickman and Aquino, 2004). In 2004, the International Rice Research Institute (IRRI) in collaboration with GrainPro, Inc. developed a 50-kg capacity hermetic bag called the "IRRI Super Bag" that fits inside a traditional storage bag or jute sack meant to be used by seed growers and subsistence farmers. Years of evaluation, dissemination and promotion of the IRRI Super Bag prompted other suppliers to come up with their own versions of hermetic bags and other hermetic containers as well. In 2011, IRRI obtained samples of different types of hermetic bags and sent them to a gas transmission laboratory and testing center for evaluation of oxygen permeability. Results of the test for oxygen transmission rate (OTR) of the hermetic bags in $ml/m^2 \cdot d$ were as follows: IRRI Super Bag (39), GrainPro SGB IIZ (0.6), Kantong Semar (1.9) and Pioneer (1470). The study was conducted to confirm the oxygen permeability report and to evaluate the effect of various hermetic storage options on the germination and milling characteristics of paddy rice.

MATERIALS AND METHODS

Paddy rice of the same variety (NSIC Rc148) and harvested from the same field was dried at 43^oC using a recirculating dryer. Dried paddy rice was stored in various hermetic units: IRRI Super Bags (IRRI SB), GrainPro SGB IIZ bags (ZIP), Kantong Semar bags (KS), Pioneer bags (PIO), Purdue Improved Cowpea Storage bags (PICS) and 100-kg capacity household metal silos (SILO) that are airtight and maintain the quality of stored products (Muhindi, 2008; AGST FAO, 2008). Dried paddy rice was also stored in ordinary woven sacks that served as the control (CTRL). The paddy rice was infested with stored insect pests at different growth stages with a ratio of 10 insects/kg before sealing. Oxygen (O_2) content and carbon dioxide (CO_2) content inside the hermetic options were monitored daily for 14 days and then weekly using Bacharach CD 98 plus multi-gas analyzer. Samples weighing 500 g from the various hermetic options were taken initially (INTL) and then after 3 months and 6 months of storage. These samples were evaluated for moisture content (m.c.), live insect count (LIVE INS), germination (GR), 500 grain weight (500 GW), discoloration (DSCLR), whiteness (WHT), milling recovery (MR) and head rice recovery (HRR). Samples were set up using a randomized complete block design (RCBD) and sample means were analyzed using analysis of variance at the 95% level of significance by RCropStat version 2.11.1 statistical software developed by the IRRI Crop Research Informatics Laboratory Unit.

RESULTS AND DISCUSSION

Oxygen (O_2) Content

From day 1 up to day 13 of storage, all hermetic options exhibited O_2 content >15% but, at day 22, IRRI SB, ZIP, KS and PICS exhibited O_2 content <10%. At day 56 of storage, there was a noticeable upward spike in the O_2 content of all hermetic options except SILO, which maintained its O_2 content >15% (Fig. 1A). This spike may be attributed to a combination of low live insect count and a high point in the oxygen that permeated through the plastic film of the hermetic bags from the outside atmosphere. At 105 days after storage and thereafter, IRRI SB, ZIP, KS and PICS exhibited O_2 content <10% while O_2 content of PIO was 10-14% and SILO 16-19%. The pattern in Fig. 1A is typical for hermetic storage systems where oxygen levels drop fast until most insects are killed and respiration processes are minimized. Oxygen leaking through the plastic film then leads to an increase of oxygen levels that favors insect development, which in turn reduces oxygen levels again after some time.

Carbon Dioxide (CO_2) Content

From day 1 up to day 29, IRRI SB, ZIP, KS and PICS showed an upward trend in CO_2 content (Fig. 1B). This may be attributed to the insects steadily consuming the oxygen inside the hermetic bags. From day 35 to day 82 of storage, CO_2 content of previously mentioned hermetic options declined steadily (Fig. 1B), which may be attributed to a corresponding insect population decline inside the bags and also CO_2 leaking out of the plastic film through osmosis. After 29 days of storage and thereafter, IRRI SB, ZIP and KS exhibited similar CO_2 trends with readings from 9.0% to 13.5% at the higher end while, at the lower end, PIO and SILO displayed similar trends with readings of 1.4-5.4%. The CO_2 trend of PICS was in the middle with readings of 3.4-9.2%.

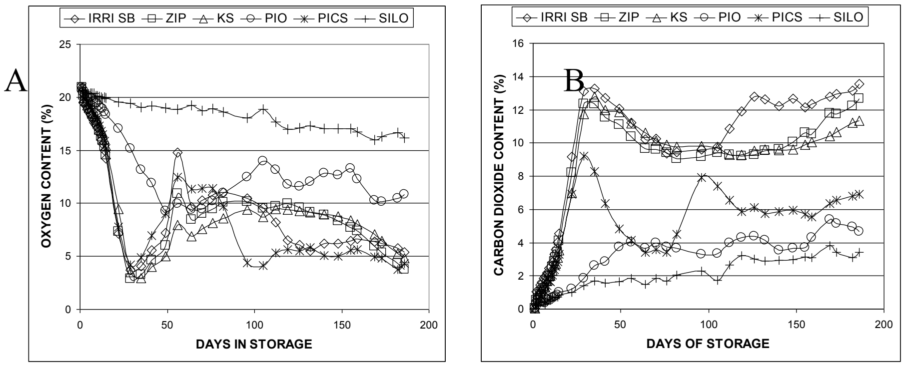

Fig. 1- Oxygen content (A) and carbon dioxide content (B) trends of inside atmosphere of various hermetic options during 6 months of storage

Moisture Content (m.c.)

At 3 months of storage, the MC of ZIP (12.0%) was significantly lower than the MC of INTL and all the other hermetic options (Table 1) while, at 6 months, there was a significant difference between the MC of KS (12.2%) and SILO (12.9%) (Table 2).

Live Insect Count (LIVE INS)

At 3 months, the CTRL displayed significantly higher LIVE INS compared with the other hermetic options (Table 1). At 6 months, the LIVE INS of SILO and CTRL were higher than with the other hermetic options although only SILO was significantly different (Table 2). Note also that, at 6 months, all hermetic bags except PIO exhibited LIVE INS < 0. Fixed structures like metal containers are difficult to seal properly. Also, they do not adjust their volume to atmospheric pressure changes and therefore under and overpressures can lead to leakages.

Germination (GR)

At 3 months, CTRL (67.3%) had the lowest GR but only ZIP (84.3%) was significantly higher than CTRL among the other hermetic options (Table 1). At 6 months, SILO (54.0%) had the lowest GR, which was significantly different from INTL, PICS, PIO and ZIP (Table 2). The low GR of CTRL and SILO may be due to increased insect damage of grains compared with the other hermetic options.

500 Grain Weight (500 GW)

At 3 months, CTRL (12.2 g) had the lowest 500 GW, which was significantly different from INTL, ZIP, KS, PIO and SILO, which all had 500 GW >13 g (Table 1). At 6 months, CTRL (10.4 g) again displayed the lowest 500 GW, significantly lower than that of INTL, IRRI SB, KS and PICS (Table 2). Although the MC at sampling was similar to that of the other treatments, open storage leads to moisture fluctuations and therefore to increased respiration, causing higher dry matter loss. Insect damage to grains can also be credited for the decrease in grain weight.

Discoloration (DSCLR) and Whiteness (WHT)
At 3 months and 6 months of storage, analysis of variance of sample means exhibited no significant difference between treatments (Tables 1 and 2). This means that the various hermetic options had no effect on the DSCLR and WHT of the paddy rice stored.

Milling Recovery (MR)
At 3 months, CTRL (64.0%) showed significantly lower MR than the rest of the hermetic options (Table 1). At 6 months, all the hermetic options, with the exception of PIO (64.4%), had significantly lower MR than INTL (66.9%) (Table 2).

Head Rice Recovery (HRR)
At 3 months, IRRI SB (84.2%) had the lowest HRR, significantly different from the HRR of KS (86.3%) and INTL (89.0%) (Table 1). At 6 months, HRR of INTL (89.0%) was significantly higher than that of all the other various hermetic options (Table 2).

Table 1. Germination and milling characteristics of paddy stored in various hermetic options after 3 months of storage*,**

TRMT	*m.c. (%)*	*LIVE INS*	*GR (%)*	*500 GW (g)*	*DSCLR*	*WHT*	*MR (%)*	*HRR (%)*
INTL	12.8 a	5.0 c	89.0 a	13.3 a	13.9	40.6	66.9 a	89.0 a
CTRL	13.0 a	121.3 a	67.3 b	12.2 b	14.9	42.1	64.0 c	85.2 bc
IRRI SB	13.0 a	19.7 c	83.0 ab	13.0 ab	16.1	41.7	65.7 ab	84.2 c
ZIP	12.0 b	3.3 c	84.3 a	13.1 a	15.3	41.8	65.7 ab	85.5 bc
KS	13.0 a	4.4 c	79.3 ab	13.2 a	11.9	41.7	65.4 b	86.3 b
PIO	12.7 a	41.0 bc	77.3 ab	13.0 a	12.9	41.5	66.0 ab	85.8 bc
PICS	13.0 a	4.3 c	79.7 ab	12.7 ab	13.7	42.1	65.6 ab	85.7 bc
SILO	13.0 a	84.0 ab	75.0 ab	13.2 a	13.0	41.4	65.4 b	85.8 bc

* Means within a column with the same letter are not significantly different ($p<0.05$)
**TRMT=treatment, m.c.=moisture content, LIVE INS=live insect count, GR=germination rate, 500 GW=500 grain weight, DSCLR=discoloration, WHT=whiteness, MR=milling recovery, HRR=head rice recovery

Table 2. Germination and milling characteristics of paddy stored in various hermetic options after 6 months of storage*,**

TRMT	*m.c. (%)*	*LIVE INS*	*GR (%)*	*500 GW (g)*	*DSCLR*	*WHT*	*MR (%)*	*HRR (%)*
INTL	12.8 ab	5.0 b	89.0 a	13.3 a	13.9	40.6	66.9 a	89.0 a
CTRL	12.3 ab	105.0 ab	72.0 ab	10.4 b	12.9	41.4	62.0 b	84.4 b
IRRI SB	12.5 ab	0.0 b	74.3 ab	12.8 a	10.8	41.3	63.9 b	84.7 b
ZIP	12.5 ab	0.7 b	81.7 a	12.3 ab	11.6	41.4	63.8 b	83.5 b
KS	12.2 b	0.7 b	80.0 ab	12.6 a	12.2	41.2	63.2 b	85.2 b
PIO	12.5 ab	18.7 b	83.0 a	12.3 ab	10.9	41.4	64.4 ab	85.5 b
PICS	12.4 ab	0.3 b	86.3 a	12.7 a	12.0	40.9	63.8 b	84.8 b
SILO	12.9 a	159.3 a	54.0 b	12.4 ab	13.3	41.8	63.1 b	85.4 b

* Means within a column with the same letter are not significantly different ($p<0.05$)
**TRMT=treatment, m.c.=moisture content, LIVE INS=live insect count, GR=germination rate, 500 GW=500 grain weight, DSCLR=discoloration, WHT=whiteness, MR=milling recovery, HRR=head rice recovery

CONCLUSIONS

The following conclusions were drawn from using various hermetic options to store paddy rice for 6 months:

- The oxygen content trend for 6 months confirms the lab test report that PIO has significantly higher oxygen permeability than IRRI SB, ZIP and KS.
- Hermetic bags are still permeable to oxygen from the outside atmosphere but different bags have different permeability.
- Some hermetic bags not only prevent oxygen from penetrating inside the stored paddy rice but also prevent carbon dioxide from leaking out of the bags, evidenced by high CO_2 content readings (Fig. 1B).
- Metal silos are the least hermetic among the other options evidenced by the oxygen content not going below 15% and very high live insect count after 6 months of storage.
- Insect activity in all hermetic options except metal silos declined significantly.
- Germination rate, grain weight, milling recovery and head rice recovery were lowest when no hermetic options were used to store paddy rice due to the presence of insects in the stored paddy rice.
- The various hermetic options had no effect on the discoloration and whiteness of the stored paddy rice.

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