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ADOPTION OF HERMETIC STORAGE ON MILLED RICE USING THE VOLCANI CUBE® IN THE PHILIPPINES

CECILIA V. DE DIOS,[1]* MARIA FINESA A. COSICO,[1] D.D. JULIAN,[2] J.V. DATOR,[2] ELVIRA M. MARTINEZ[1] AND R.L. TIONGSON[2]

[1]*The National Food Authority (NFA), Technology Resource Development Department, Technical Research Division, Quezon City, Metro Manila, Philippines*
*[*e-mail: memm@nfa.gov.ph]*
[2]*Bureau of Postharvest Research and Extension, Munoz, Nueva Ecija, Philippines*

ABSTRACT

A pilot trial was conducted on the adoption of hermetic storage using Volcani Cubes for long-term storage of milled rice at the National Food Authority (NFA) Warehouse in Cabanatuan City, N.E., Philippines. The storage cubes consist of an upper and a lower section of plastic sheeting zipped together to provide an hermetic seal. The objective of this trial was to evaluate the preservation of milled rice in the cubes without employing fumigants in a tropical climate. Nine stacks of milled rice imported from Vietnam were kept in Volcani Cubes; three untreated control stacks were used as reference. Initial infestation was extremely low due to the recent fumigation of the test commodity. After 3, 6 and 11 months of continuous storage, oxygen concentrations in the Volcani Cubes dropped to 11.4%, 5.4% and 2.7% respectively. The hermetic conditions suppressed insect development and, where the atmospheres contained sufficiently low levels of oxygen, mortality of insects was achieved. The modified atmospheres were able to retard insect growth and development, as evidenced by weak and abnormal progeny of *Rhyzopertha dominica*. This is further supported by the decrease in live insect counts. The quality of rice stored under hermetic conditions in the cubes remained high throughout the storage period. In contrast, the untreated control stacks stored in a normal warehouse atmosphere were heavily infested after three months of storage. Between 4 and 6 months of storage, 6 out of the 9 stacks in Volcani Cubes showed insect holes presumably inflicted by *R. dominica,* but damage to the commodity was negligible. Further refinements were suggested for this environment- and user-friendly hermetic storage technology for the quality preservation of milled rice without the use of fumigants, in the Philippine climate.

INTRODUCTION

The National Food Authority (NFA) in order to fulfill its mandate of stabilization has adopted the strategy of "selective intervention" which means procuring palay (paddy rice) or corn from areas where the prevailing ex-farm prices are lower than that of the government support price. To assure the stable supply of the staple grains, appropriate measures relative to grain preservation and maintaining grain quality and quantity must be undertaken by the NFA, specifically in the conduct of its field procurement and storage activities.

The search for viable technologies and improved postharvest systems is a continuing program being undertaken by the NFA. The agency is particularly receptive to new technologies that offer alternative solution to problems being faced by the grains postharvest industry. Prior to adoption, these technologies are assessed and evaluated as to their potential for improved and cost-efficient operations (Anon., 1998).

The Bureau of Postharvest Research and Extension (BPRE) in collaboration with the Agricultural Research Organization (ARO) Volcani Center of Israel, has developed and promoted the use of plastic enclosures for outdoor storage. Outdoor storage of dried grain stocks with full insulation under sealed plastic enclosures addresses the problem of deterioration and loss of large quantities of palay and corn arising from inadequate storage facilities.

To provide an alternative storage facility for preservation of dried stacked grain in the open without the need for chemical pesticides, BPRE transferred to NFA twenty units of the 15 m^3 capacity Volcani Cubes® in conformity with a MOA signed by the two parties. These units were distributed to NFA throughout the country.

It is under this context that the "Volcani Cube" method of grain storage, which applies the hermetic principle was evaluated specifically to validate the technical feasibility and determine operational efficiency of the cubes for storage of milled rice. The collaborative study with BPRE also aims to evaluate the benefits derived and the problems/constraints that are anticipated from the introduction of the technology in NFA operations.

MATERIALS AND METHODS

The storage trials were carried out at NFA Warehouse No. 5 in Cabanatuan City using a total of 2,220 50 kg bags or 111 tonnes of imported milled rice from China (var: CM2) at an average moisture content (m.c.) of 12%. Although the Volcani Cube is also designed for outdoor storage, it was decided that in this particular trial being the first for milled rice, it would be implemented inside a warehouse.

Storage preparation

An area of about 100 m^2 of cemented ground inside warehouse No. 5 was selected and cleaned of dirt, stone and sharp objects. Although one of the requisites for site selection is to avoid rainwater accumulation, this particular warehouse, which is known to be flood-prone was the only one available at the time. Previously, warehouse No. 5 formed the road between warehouse No. 3 and warehouse No. 7 at the grain storage complex, which explains its lower elevation from the others.

Construction of the stacks

Six units of 15 m^3 capacity Volcani Cubes were used for treatments 1-6 containing 270 bags per stack and totaling 1,620 bags (81 tonnes) of the imported milled rice and three uncovered stacks served as control, containing 201 bags (10.05 tonnes) per stack.

The Volcani Cubes were loaded with strict adherence to the supplied instruction manual (Anon., 1999). The bottom portion of the cube-liner was spread out on the ground and the bags of milled rice were built directly on the liner No pallets were used. Approximately 10 layers were built inside the cube at 27 bags per layer. After the stack had been built to the required height, which is approximately 2 m, the top section was then placed over the stack to meet the lower part halfway up the side and then zipped together to form the cube. The stacks were built with a slight peak so that rain-water could run off the cube immediately in case of a heavy downpour. It was noted that the roof of the warehouse had some holes.

The control stacks consisted of milled rice placed on 3 layers of wooden pallets to raise and protect the stacks from flood water during the rainy season, with additional protection using ordinary plastic (sack material) covering. The sealed stacks required no elevation since the cubes are waterproof. The control stacks were treated with regular pest control measures as per 'Standard Operational Procedure' in NFA storage operations.

Monitoring of grain temperature and oxygen concentration

Three thermocouple wires and a length of plastic tubing were placed inside the sealed cubes containing stacks numbered 2, 5 and 8, to monitor grain temperature and oxygen concentration respectively. The temperature measuring points were located: A - directly beneath the liner, B - 10 cm down from top, C - 1 bag down from top, and D - at the center of the cube (Fig. 1). The temperature sensors were manually monitored using a thermistor thermometer. Changes in the concentration of oxygen (O_2) inside the cubes were measured daily for 30 days and once a week thereafter with a Bachrach oxygen meter. Temperature readings were taken 3 times a day on weekdays only.

Sampling

Initial sampling was conducted during the building of the stacks and final sampling upon opening of the stacks, to determine changes in the quality of the stored milled rice at the end of each storage period. Opening of the sealed and control stacks (2 Volcani Cubes and 1 control for each storage period) were after 3 months, 6 months and 9 months. However, the last sampling period for the Volcani Cubes did not materialize on the 9-month storage period due to instrument malfunction. The oxygen meter broke down and replacement was undertaken only at the 11th month. For each sampling, 10 representative samples of 1 kg each per layer were collected from each stack using a sampling probe. The same sampling procedure was followed with the control stacks.

Quality evaluation

Initial and final samples were collected and submitted to the laboratory for analysis of m.c., insect infestation, yellowing and insect damaged kernels. Calculation of quality parameters was determined manually by counting the number of insect damaged and discolored kernels in 100 g kernel samples taken from the composite samples. The actual weight loss was calculated as the difference in weight of bagged milled rice at the start and at the end of the storage trial.

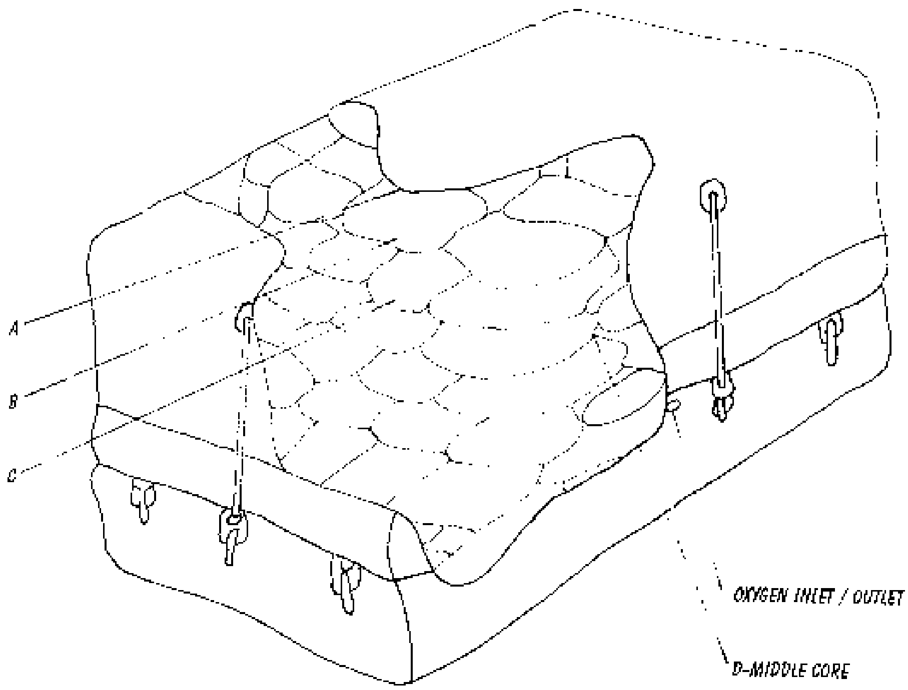

Fig. 1. Diagram of experimental stack showing temperature sensors at various points: a - beneath liner; b - 10 cm down from top; c - 1 bag down from top; d - middle core.

Moisture content determinations were carried out using a Dickey John moisture meter. Species identification and degree of infestation were analyzed by sieving the samples. All insects dead and alive, were isolated, identified and counted. Data gathered were evaluated and statistically analyzed.

RESULTS AND DISCUSSION

Moisture contents

The m.c.'s of the sealed and control stacks during storage ranged from 11.21% to 12.94%. The m.c.'s of the control and sealed stacks were all in the safe range for storing grains (Table 1). Analysis of Variance, revealed that the m.c. of milled rice held in hermetically sealed storage was significantly higher than the m.c. of the control (un-sealed) stacks with mean m.c.'s of 11.72% and 11.69% respectively. However, it was observed that there was a trend towards increase in m.c. of rice in the control stacks as compared to the sealed stacks. The overall m.c. of the hermetically stored milled rice remained practically unaffected which corroborates the findings of BPRE in a previous trial (Navarro, *et al.*, 1996). This indicates that neither moisture loss nor gain occurs in the sealed storage. The results obtained also imply that the problem of weight reduction of milled rice due to moisture loss during ordinary warehouse storage can be minimized by the hermetic method of storage.

TABLE 1
Comparison of average moisture contents of milled rice under airtight and conventional storage conditions

Storage period (months)	Sealed stacks	Control stacks
0	11.97	11.64
3	11.43	11.69
6	11.76	11.74
Mean	11.72	11.69

Grain temperatures

The mean weekly daytime temperature readings recorded from the various points within the sealed stacks were lower than those of the uncovered (control) stacks. Furthermore, less temperature fluctuations occurred inside the sealed stacks than the control stacks (Figs. 2 and 3). From this it may be deduced that the gastight storage technique reduced heat transfer from the periphery of the stack into the grain mass.

Oxygen concentrations

Oxygen concentrations in the cubes from the beginning of storage up to 6 months is shown in Fig. 4. Oxygen concentrations decreased progressively from 21% at the start of the trial to 11.4% at 90 days and 5.4% after 180 days. The lowest reading was 3.6% recorded on the 326th day (until which time the storage period was extended due to instrument malfunction). This O_2 deficient atmosphere was able to suppress the stored-product insect population as evidenced by the low density of insects in sealed stacks compared to the control (Table 2). It should be noted that in order to achieve complete disinfestation of the commodity in sealed storage, the O_2 level should be reduced to less than 2%.

Insect infestation

Most of the insect species collected from the samples were Coleoptera (beetles) and Psocoptera. The populations of storage pests in the experimental stacks are shown in Table 2. It is worth mentioning that dense populations of dead psocids were found around the bottom of the plastic sheet upon opening of the sealed stacks at every sampling period.

TABLE 2
Mean population of insect pests per 1 kg of milled rice stored in sealed Volcani Cubes and unsealed stacks

Storage period (months)	*R. dominica*		*O. surinamensis*		Psocids	
	Live	Dead	Live	Dead	Live	Dead
Volcani Cubes						
0	0	0	0	0	0	cbc*
3	12	10 + 1 larva	0	0	53	cbc
6	19	12+ 1 larva	16	32	7	cbc
Controls stacks***						
0	0	0	0	0	0	cbc
3	25+4 larvae	29	0	0	87	cbc
6	22	26 + larvae+	144	135++	TNC**	cbc

*could not be counted due to disintegration of body-parts
**TNC - too numerous to count
*** with application of regular pest control measure (protective spraying, fumigation and fogging)

At three months storage, adults and nymphs of *Liposcelis bostrichophila* (Psocidae) were found in significant numbers in all the stacks. The dead adult and immature psocids had already disintegrated and appeared like specks of dust rendering it difficult to isolate individuals for counting. One of the major Coleopteran pests encountered was *Rhyzopertha dominica* (the lesser grain borer). A primary pest, the larval and adult stage can bore inside the grain feeding on the starchy interior, and leaving irregularly shaped holes. Samples infested with *R. dominica* could be easily identified as some adults remained inside the grains. On the 6th month of storage, significant numbers of live and dead individuals of *R. dominica* and *Oryzaephilus surinamensis* were observed in the control stacks.

Populations of *L. bostrichophila* were observed to thrive in great numbers in the control stacks at 3 months of storage, while at 6 months of storage, a heavy build-up of *L. bostrichophila* became apparent. The population of *O. surinamensis* abruptly rose after the 3rd month while *R. dominica* revealed a slight increase from the previous storage period.

L. bostrichophila. was observed to have been completely eradicated after 6 months, or more specifically on the 11th month extended storage period in the sealed cubes. Data for this period were omitted in Table 3 since the control stack had to be disposed of on the 9th month due to a lack of rice supply in the area. High mortalities of *R. dominica* were also observed in all sealed stacks during the said period and it was noted that no live insects were found in the samples. Other dead insects identified were *Cryptolestes ferrugineus* (rust-red grain beetle) and *O. surinamensis*.

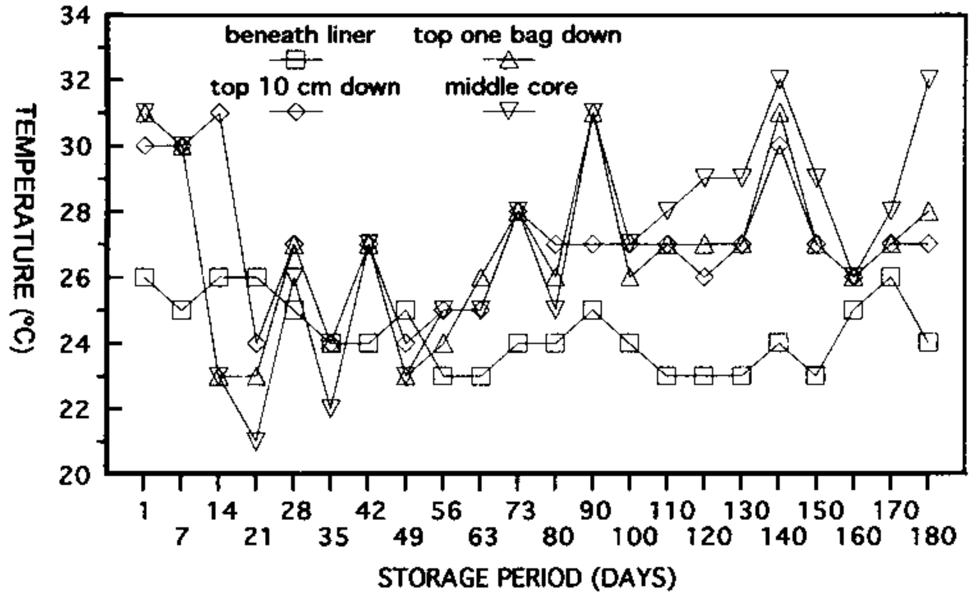

Fig. 2. Temperatures recorded from various points in the sealed Volcani Cube No. 5.

Climatic conditions

Flooding due to heavy rains occurred twice in the area. The drainage within the warehouse overflowed because of a heavy downpour that lasted for more than 2 hours. The first flooding happened a month before the opening of stacks stored for 6 months. The second occurred between the 9th month and the 11 month (extended) storage period of the last 2 sealed stacks. Pin-size holes at the bottom of the plastic liner created entry points for water seepage. Seepage at floor level of the plastic liner caused damage to some bags located at the bottom layer. *R. dominica* is known to be capable of boring holes through plastic. Furthermore most of the holes were located near the seams of the plastic where several live individuals were observed to be clinging. This may be the point where the permeation of O_2 from the external atmosphere to the cube is greater thus enabling the insects to follow the O_2 gradient.

Quality Parameters

Discolored Grains (Yellow Kernels): Discoloration is a commonly used parameter to indicate milled rice quality (Table 3). It expresses heat damage or mold activity. ANOVA analysis revealed that the percentage increase in yellow kernels of milled rice held in the Volcani Cubes was significantly higher than in the unsealed control stacks. However, when the results were subjected to Duncan's multiple range test, the percentage of yellow kernels of milled rice obtained from sealed stacks did not significantly differ from those of the control stacks.

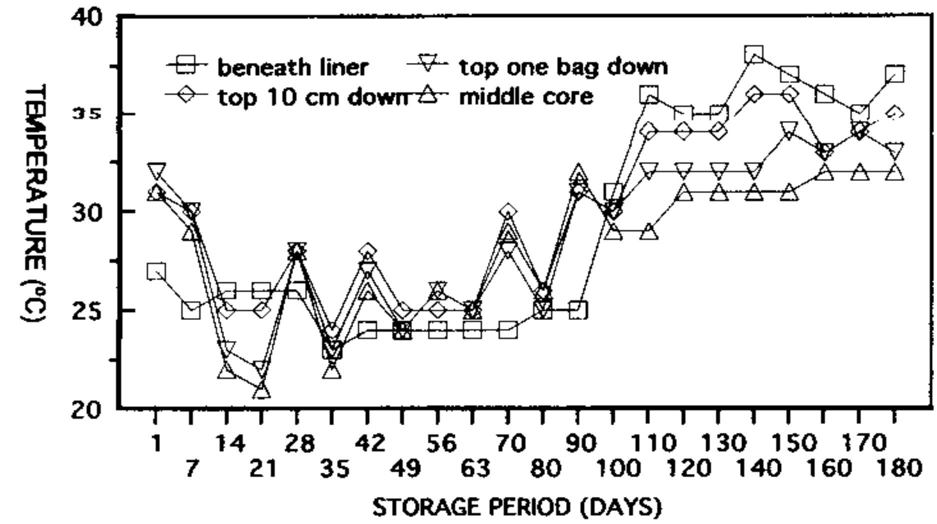

Fig. 3 Temperatures recorded at different points in the control stack.

Insect Damaged Kernels: Table 4 reveals a marked increase in insect-damaged kernels in the control stacks over time, whereas only a slight increase in insect damage was recorded in the sealed stacks. This shows that the airtight storage protected the rice from insect damage. ANOVA analysis showed that numbers of insect-damaged kernels increased significantly as storage was prolonged.

TABLE 3
Yellowing of milled rice in conventional and airtight storage systems

Storage period (months)	Sealed Volcani cubes	Unsealed control stacks
0	0.94	0.48
3	2.07	1.71
6	1.44	2.34

TABLE 4

Average insect damaged kernels (%) of milled rice stored in sealed Volcani Cubes and unsealed stacks

Storage period (months)	Sealed Volcani cubes	Unsealed control stacks
0	0.35	0.26
3	0.36	0.47
6	0.84	1.17

Weight Loss: The losses in weight of the milled rice at various sampling stages are shown in Table 5. After 3 months of storage, weight loss in the control stack was 5 times higher than in the sealed stack. In spite of the flood-water damage, the sealed enclosure registered a mean weight-loss of 0.37% while the control suffered twice as much. These results indicate that weight loss is effectively reduced through sealed storage. The higher weight loss in the control stacks was due to insect infestation and rodent and bird attack.

TABLE 5
Loss in weight of milled rice in sealed and conventional systems of storage

Stack No.	Storage period (months)	% weight loss
Sealed Volcani Cubes		
1	3	0.08
2	3	0.07
3	3	0.05
4	6	0.58*
5	3	0.03
6	3	0.51*
Unsealed control stacks		
1	3	0.39
2	6	0.72

* flood-water damaged

In view of the damage of the commodity by flood-water in three sealed stacks actually experienced here, we conclude that it is imperative that an elevated site be selected. Moreover, the ground should be free from cracks and crevices to prevent soil insects from damaging the cube from the outside.

In general, adoption of hermetic storage using Volcani cubes as an alternative method of milled rice storage is recommended. The Volcani Cube being a 'green' technology provides a safe alternative to storage methods that make use of pesticides and the attendant risks associated with chemical use. In addition, the ease by which the cube can be moved from one place to another gives the NFA the capability to handle grains in areas where storage facilities are lacking or nonexistent. It can also be used as a temporary storage facility for the agency's mobile procurement and port operations. The technology is relatively easy to implement saving time and labor costs.

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