Commercial Experience of Sealed Storage of Bag Stacks in Indonesia

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Abstract

BULOG has adopted the use of sealed plastic enclosures purged with CO_2 as one option for the long-term storage of bagged, milled rice. This system has been successfully implemented in two phases beginning in 1984 and since then some 90.000 tonnes of milled rice have been stored for periods up to 2.5 years. Although the technique has been an operational success, in that the outturn quality has met with considerable approval, technical and managerial improvements are possible.

Technically, there is a need for further developments to reduce costs, by increasing the potential for reuse of sheets and by lowering the rate of failure in gas retention. It is believed that the failure rate could be much reduced by further technical refinement.

On the management side, there remains considerable scope for the full integration of the CO_2 method into BULOG's operational system. This could be achieved through a more comprehensive cost–benefit analysis, better forecasting of requirements for long-term storage, and more accurate identification of the best locations for long-term stocks. It appears that the CO_2 system may become a permanent feature of the BULOG rice storage system, its extent being governed by the need for longer term storage.

THE long term storage of bagged, milled rice under carbon dioxide (CO_2) in fully sealed plastic enclosures offers an alternative to the regular use of fumigation and insecticide spraying for grain preservation. The initial development of the technique was undertaken by CSIRO in Australia, and the technology transferred to the humid tropics through a collaborative small-scale project with BULOG, at Tambun, West Java (Annis et al. 1984). The technique was successfully used to store about 700 tonnes of rice, with a 12% moisture content, for periods of up to 4 months. The practicalities of implementing the technique were considered and it was found that the enclosures could be built by two men in just over an hour.

As the method was clearly practicable, BULOG undertook a larger scale trial using 6400 tonnes of rice at 13-14 % moisture content (Sukardi & Martono 1984; Suharno et al. 1984). This trial compared the use of CO_2 and phosphine in sealed enclosures for periods of up to 16 months. From the results, it was concluded that CO_2 treatment was more effective than phosphine in controlling both insect pests and mould growth and would be ideal for use in long-term storage, provided the enclosures remained undamaged. Some consideration was also given to the economics of the method. An analysis was performed on costs and anticipated rice losses. This gave the minimum break-even period with normal pest control methods as about 9 months. Later analysis based on costs alone put the break-even period at about 12 months (Suharno 1986)

Against this background of successful experimental trials, it was with some confidence that BULOG embarked upon operational CO_2 storage in 1984. To date, some 90,000 tonnes of milled rice have been stored at various locations in Indonesia (Table 1). The

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techniques employed are summarised in the Appendix. This short paper describes the operational methods used by BULOG, gives summaries of some of the data collected by the operational teams, and considers technical and management aspects that might be improved.

Operational Considerations

CO_2 Concentration

Stocks in the BULOG system are purged with CO_2 to give an initial concentration of the gas of 80%, declining to a minimum of 50% after 10 days and not less than 10% after 6 months. This dosage schedule is somewhat higher than the latest recommendations for the technique, which are for 70% CO_2 initially, declining to 35% after 15 days or longer (Annis 1986). At the time the technique was developed in Indonesia, an initial concentration of 60% was required. However, this was increased when live, but moribund, specimens of *Sitophilus oryzae* were discovered some weeks after treatment. It is well established that this species is particularly tolerant of CO_2(Annis 1986).

Table 1. Tonnages of milled rice preserved at various locations in Indonesia using the CO_2 method

Region	Phase1	Phase2	Total
Jakarta Raya	28200	14116	42316
West Java	4750	0	4750
Central Java	2700	1500	4200
East Java	11578	19730	31308
South Sulawesi	4900	0	4900
North Sumatra	4500	0	4500
Total	56628	35346	91974

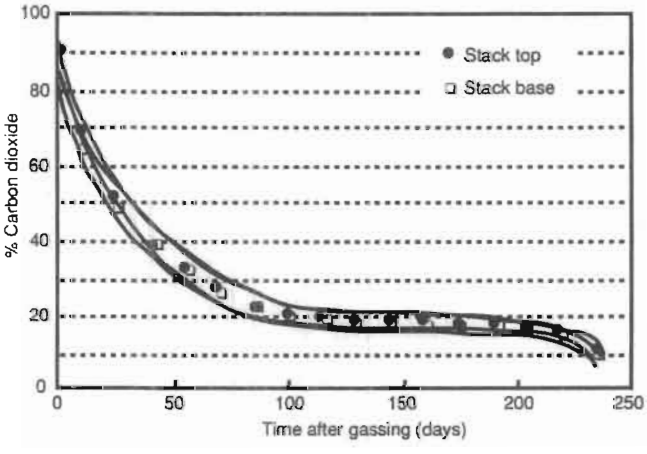

Figure 1. Mean CO_2 concentration in rice stacks.

The gas levels achieved in 57 rice stacks in East Java during the 1987–88 program are shown in Figure 1. (Data from stacks with substantial leaks have not been included.). The profile of decline in gas concentration matches that recorded during experimental studies by Sukardi and Martono (1983). The concentration regime has been successful in destroying existing infestations and preserving rice quality.

Two practical questions concerning the gas concentration are worthy of consideration:

a) Is it necessary to insist on so high an initial gas concentration?

b) What should be done if the gas concentration drops below 10%, as it invariably does after about 8 months, and continued long-term storage is envisaged?

Currently, BULOG regulations would stipulate regassing, but there is no conclusive evidence that this is necessary. If regassing is performed, it is not known what extent of regassing would be cost effective for any given additional storage period.

Failures in Gas Retention

Gas retention failure in stacks can take three forms:

(a) large gas leaks in the first 10 days, resulting in the initial fumigation by CO_2 being ineffective;

(b) subsequent failures due to large holes made in the sheets by, for example, rodents; and

(c) failures due to small leaks that result in a gradual fall in the CO_2 concentration to below 10% during the first 6 months after gassing.

The frequency of failure has been found to

Table 2. Records of failures in gas retention at various locations in Indonesia (incomplete data).

Location	No. of stacks	No. of failures	% Failure
Jakarta	109	32	29
West Java	12	7	58
Central Java	16	0	0
East Java	70	13	17
South Sulawesi	6	3	50
North Sumatra	12	2	17

vary between locations (Table 2) averaging around 25%. Much higher failure rates were encountered in those stores suffering from heavy rodent infestation, e.g. in West Java, South Sulawesi, and Jakarta (Table 2). In East Java, about 17% of stack treatments failed. In the first 10 ten days after purging, 3 of 70 stacks required regassing. These failures all occurred at a particular site and, together with the somewhat higher than specified gas dosages needed to achieve an 80% initial concentration, resulted in use of an average of 3.2 rather than 2.4 kg of CO_2/tonne. In the most recent phase of CO_2 storage in East Java, failures to retain more than 10% gas were remedied without financial loss as the stocks concerned were distributed soon after the enclosure atmosphere had fallen below 10% CO_2. While this management option may frequently present itself, in a well planned CO_2 program where all stacks are stored for the minimum period required to break-even with normal stock protection methods, such failures would necessarily represent an undesirable loss.

Recorded causes of failures are rodent damage, inadequate sealing, manufacturing defects in the plastic sheets, and holes caused by contact with the wooden pallets. Birds and insects (e.g. *Rhyzopertha dominica*) made holes in sheets on only two occasions. It seems probable that the failure rate could be much reduced if (a) an effective anti-rodent strategy involving rodent barriers and poison baits were developed for those godowns used in the CO_2 program, (b) better quality sheets were used, and (c) pallets were abandoned and the bags stacked directly on the base sheet.

Rice Quality and Value

Quality changes in rice stored for 70–250 days under CO_2 in East Java are given in Table 3. Samples were taken from marked bags on the stack surface at the start of the storage period and again from the same bags at the end. All the sampling and analyses were undertaken by Pest and Quality Control staff as part of their normal routine.

Overall, there seems to be a general trend towards a small increase in the numbers of brokens and yellow grains, and in the moisture content. Small increases in moisture content and yellowed grains in the outer bags of stacks have been observed previously (Sukardi and Martono 1983; Suharno et al. 1984). In contrast, observations on rice stored in Jakarta for 2.5 years showed a very slight decrease in moisture in the outer layers, but agreed in other respects. In Table 3 a comparison is also made of quality factors for stacks which had a period of storage at below 10% CO_2 concentration for an average of 34 days (range 15–66 days), with those from stacks maintained at a higher concentration throughout the storage period. It would appear that storage at the lower concentration had, on average, no detrimental effects. In fact, the rice quality from these stacks appeared somewhat better. Even those stacks held for the longest

Table 3. Quality analysis of rice from the East Java CO_2 program (Mean % ±sd)

Storage period (days)	Number of stacks	M.C. Start	M.C. Finish	M.C. Change	Brokens Start	Brokens Finish	Brokens Change	Yellow\Damaged grains Start	Yellow\Damaged grains Finish	Yellow\Damaged grains Change
70–100	17	13.41	13.83	0.43	22.82	24.44	1.62	2.30	2.28	−0.03
		0.36	0.11	0.37	3.38	2.50	2.81	0.58	0.57	0.40
101–200	24	13.42	13.38	−0.04	26.29	28.25	1.96	2.22	1.98	−0.24
		0.32	0.48	0.38	2.43	3.06	3.19	0.61	0.78	0.66
201–250	21	13.44	13.74	0.32	5.37	25.42	0.05	1.62	2.19	0.57
		0.26	0.23	0.15	4.79	5.57	2.42	0.41	0.38	0.40
Overall mean ±sd		13.42	13.63	0.21	25.03	26.24	1.22	2.04	2.13	0.09
		0.31	0.39	0.38	3.89	4.30	2.96	0.62	0.62	0.62
Stacks*	47	13.40	13.64	0.24	23.88	25.51	1.64	1.92	2.01	0.10
>10% CO_2		0.30	0.39	0.41	3.59	4.40	3.11	0.54	0.54	0.63
Stacks**	15	13.48	13.60	0.11	28.33	28.35	0.02	2.40	2.47	0.07
<10% CO_2		0.35	0.38	0.25	2.64	3.18	2.05	0.68	0.73	0.60

* Mean % ±sd for stacks always maintained above 10% CO_2

** Mean % ±sd for stacks stored part time below 10% CO_2

periods at below 10% CO_2 all showed levels of deterioration comparable with those where higher levels of CO_2 had been maintained.

Throughout the period in which rice was stored under CO_2 in well-sealed plastic enclosures no mould growth was observed on stocks. This was achieved with routine inspection of incoming rice, which is accepted for conventional BULOG storage if its moisture content falls within the range of 12–14%. Thus, earlier fears that moisture related problems would hamper storage under CO_2 in sealed enclosures have been unfounded.

Laboratory analysis for quality does not necessarily confirm consumer acceptability of a stock. Information was therefore collected from the Godown Chiefs in East Java who were responsible for the distribution of rice from both the CO_2 and normal storage programs. Godown Chiefs are well placed to judge consumer reactions to the stocks they hold. Consumers choose their rice carefully and will complain at poor quality. All four Godown Chiefs where enthusiastic about the quality of rice from the CO_2 program, saying that although it may sometimes have rather less taste, it was preferred by the consumer because of its noticeably better odour, visual appearance, and the cleanliness of the jute bags in which it is provided.

Previous studies and the present observations all lead to the conclusion that the CO_2 technique provides an excellent method of quality preservation, to the extent that rice preserved under this method may be sold at a premium over similar rice stored under a conventional regime. As an example, rice stored in Jakarta for 2.5 years received an almost 8% higher price than similar stock stored by more conventional means (Table 4).

Plastic Sheets

Initial experience with plastic sheets manufactured in Australia showed that such sheets rarely had problems with gas retention as they were made of durable plastic with low permeability to CO_2, and had strong seams and a relatively high resistance to rodents. Financial constraints and government policy have forced BULOG to rely on locally manufactured sheets. Unfortunately, these are of lower quality and consequently retain gas less well. This situation might be improved if BULOG provided manufacturers with clear specifications on permeability, ageing qualities, and resistance to physical damage.

From the start of this work it was clear that the most expensive element in the use of CO_2 was the provision of plastic sheets. For this reason the ability to reuse sheets at least once is very important (this is further emphasised in another paper later in this conference). Some reuse has been achieved in the two programs but it has been observed that, especially in East Java, the sheets are stored after use in godowns that also contain rice. As a result, they are sometimes severely damaged by rodents. To improve the potential for reuse of sheets it may be worth while providing them with durable carrying cases in which they can be stored safe from rodent attack and other means of physical damage.

Problems with sheets might be further reduced if it was found possible to replace the base sheet by coating the floor beneath CO_2 stacks with a gas proof paint.

Managerial/Planning Considerations

The management and planning for the CO_2 programs has been relatively trouble-free, although it cannot yet be said that the system is used to full operational efficiency. There seem to be no problems in obtaining supplies of local plastic sheeting, glue, or gas. The pest control teams have found the technique easy to apply. Local management of CO_2-stored stocks

Table 4. Prices at sale of CO_2 stored rice and rice stored by conventional means

Wholesaler group	Price of CO_2 rice (Rp/Kg)	Price of conventional rice (Rp/Kg)	Price difference
1	225	210	15
2	230	210	20
3	230	215	15

has proven considerably easier than for conventional stocks. Apart from rodent eradication, there has been no need for routine pest and quality control activities or store cleaning and the stores can be kept locked for most of the time. However, the CO_2 technique does include some extra duties for godown staff, in particular monitoring CO_2 con-centrations, checking for holes in the sheets, and quality analysis of samples taken from the stocks before and after storage. All Godown Chiefs questioned considered that their responsibilities were much less onerous with the CO_2 program and they considered that losses, especially those through pilfering, were much reduced. All the Godown Chiefs were keen for the continuation of the program.

There have been some problems arising from the following aspects of central management:

(a) planning and scheduling of the distribution of materials for the preparation of the plastic enclosures has not always been done in sequence with rice procurement; and

(b) information on which stocks are likely to be required for longer term storage and their locations has not always been available. The difficulties of accurate forecasting in the most recent program resulted in many stocks not being maintained long enough for the costs of CO_2 storage to break-even with insecticide spraying and fumigation.

Conclusions

The successful application of the CO_2 technique to about 90,000 tonnes of rice since 1984 has led to the establishment of the method as one of BULOG's main options for the long-term storage of milled rice. The extent of its use in the future will be determined by actual requirements for long-term storage. The technique needs further development in both technical and managerial areas. Special priority should be given to:

(1) reducing the failure rate in gas retention by implementing rodent control programs, developing better specifications for locally made plastic sheets, and eliminating wooden pallets;

(2) increasing the potential for reuse of sheets through better specification of sheet quality and more careful storage of sheets between uses;

(3) precise determination of the break-even storage period between CO_2 storage and conventional techniques, based on both costs and benefits (recent progress on this is reported in another paper in these proceedings);

(4) determination of the most efficient balance between conventional pest control and CO_2 storage on the basis of sound forecasting of grain procurement and distribution; and

(5) prediction of the ideal geographical locations for long-term storage based on sound operational planning.

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Appendix

A SUMMARY OF BULOG INSTRUCTIONS FOR THE APPLICATION OF THE CO_2 TECHNIQUE

Preparation of the Stack and Enclosure

1. A PVC sheet (0.76 mm thick) is placed on the floor where the stack is to be built.

2. Wooden pallets, in good condition, are positioned on top of the sheet to leave a sheet margin of 50 cm.

3. A stack of milled rice is built on the pallets, using stock with a moisture content of about 13%. The upper surface of the stack should be level before a tailored plastic sheet is fitted over the stack.

4. The margin of the plastic base sheet, which will be glued to the plastic cover, is cleaned with detergent.

5. The edges of the base and cover are glued together using Rakol Ultra DX glue.

6. For the sampling of CO_2 gas, a plastic pipe (25 mm i.d.) is inserted through the cover at the base of the stack. The same pipe is also used testing the gastightness the stack and allows the insertion of the copper CO_2 filler pipe. A paralon pipe (12.5 mm i.d.) is inserted into a hole at the top of the stack. The paralon pipe is then connected to a plastic pipe (7.7 mm i.d.), using putty, which trails to the ground. This pipe is used for sampling CO_2 gas from the top of the stack and for air pressure measurements.

Checking for Leaks

1. A domestic vacuum cleaner is connected to the CO_2 filler pipe at the base of the stack. To monitor the vacuum, a manometer is attached to the pipe leading from the top of the stack. When the air pressure difference between the inside and outside of the stack reaches 40 cm on the manometer the vacuum cleaner is turned off. The stack is then checked for leaks and any found are repaired.

2. The vacuuming and repair are repeated until the plastic enclosure can hold a differential in air pressure of 50% for about 15 minutes.

Adding CO_2

1. The vacuum is released and a hole cut at the top of the stack to allow the escape of air when CO_2 is added below. The air pressure/CO_2 measuring pipe is closed.

2. Liquid CO_2 from cylinders, or more usually a tanker, is delivered to the stack through a copper pipe (17 mm i.d.) inserted at its base. The CO_2 will run in below the pallets. A dose of about 2.4 kg/ tonne is administered, at which time the concentration of CO_2 is measured, via the CO_2 measuring pipe inserted at the top of the stack, using a 'Cosmotector'. When a concentration of 80% CO_2 is reached gassing is complete and the vent hole and CO_2 delivery pipe are sealed.

Monitoring

After gassing regular checks are made for the following:-

1.Gas Concentration

The concentration of gas is checked every day for the first 10 days by measurement at the base and top of the stack using a 'Cosmotector'. A minimum concentration of 50% is required for the first 10 days. Thereafter, measurements are made every 15 days or earlier if a leak is suspected. If the CO_2 level reaches less than 10% in the first 6 months regassing is required after a vacuum test.

2. Damage to the System

Daily inspections are made for

- the presence of holes in the plàstic sheeting caused by rats, birds, or insects
- any loosening of the putty used to join the plastic pipe work
- any condensation under the covers
- the presence of living insects and/or micro-organisms on the surface of the stack

3. Rice Quality

The quality of rice coming from the CO_2 program is checked by sampling at the beginning and end of the storage period. Samples are taken from five marked bags on each side of a stack before the covers are put on. This procedure is repeated at the end of the storage period and the results compared.