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CORN STORAGE UNDER SEALED ENCLOSURE FUMIGATION STORAGE TECHNOLOGY (SEFUST) IN NFA OPERATIONS

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ABSTRACT

A validation study was conducted to determine the adoptability into the operations of the NFA of the SEFUST using PH_3 as a fumigant in corn storage. A comparative analysis of the costs incurred in utilizing SEFUST *vs* the existing conventional storage practice of the NFA was undertaken. The comparison between the two systems from a financial perspective showed a relatively low initial investment for the conventional storage as compared to the SEFUST. For a longer period of storage, however, the conventional storage would incur a higher cost because of the expensive pest control methods under the routine basis as normally practiced. SEFUST provides potentially cost-effective control in terms of the benefit viewed in the longer run. With regards to its technical viability, the SEFUST for corn storage using PH_3 as a fumigant showed satisfactory results in terms of effective control of infestation and prevention of re-infestation.

INTRODUCTION

Insect infestation has always been regarded as a major problem in grain storage and has been identified as the primary cause of reduction in quantity. Aside from the direct damage insects inflict on the grain, insect metabolism releases heat and moisture that promote the growth of storage fungi, thus resulting in discoloration and eventual deterioration in quality.

Under normal circumstances, the commonly employed pest control methods undertaken in National Food Authority (NFA) operations are protective spraying, residual spraying, fogging, and if necessary, the use of so-called “conventional fumigation”. In spite of this it has to be admitted that these methods of pest control leave much to be desired and until now, are regarded as major concerns that need to be addressed due to recurrent infestations in storage. These technologies do not provide continuous protection of the commodity but merely serve as a rapid method of killing insects to meet quality demands, or just form part of a routine program of insect suppression.

In view of the prevailing situation, a pilot testing of the 'Sealed Enclosure Fumigation Storage Technology' SEFUST based on the satisfactory results of a previous study entitled "Long Term Storage of Grains Under Plastic Cover" by NAPHIRE (ACIAR Project 8307) (Bautista *et al.,* 1990) was carried out. While the technical adoptability of the SEFUST technology has been established (Annis and van S. Graver 1990), its economic viability and acceptability had yet to be determined, including its advantages over the existing conventional storage practice. This specific project places emphasis on the pilot testing of SEFUST in the actual storage of yellow corn grains using phosphine (PH_3) as a fumigant, and the results obtained will form a rational basis for promoting its widespread adoption in the context of the existing NFA storage system.

MATERIALS AND METHODS

Building of stacks

One day prior to the building of experimental stacks, a non-reinforced PVC plastic floor-sheet app. 0.75 mm thick was laid on the floor. Three stacks, each consisting of 3,816 50 kg bags (190.8 tonnes) of yellow corn grain were built on standard fumigated wooden pallets normally used in NFA warehouses. Residual sprays were also applied around the warehouse at the same time.

Sealing

Subsequently, the corn stacks were covered with plastic cover-sheets (0.25-0.50 mm thick nylon reinforced PVC) pre-fabricated to the size and shape (11.3 m x 7.2 m x 4.6 m) of the stack. The lower borders (apron) of the plastic cover-sheet were sealed to the floor-sheet using PVC cement solvent glue.

Test for gas-tightness and application of fumigant

The sealed stacks were subjected to pressure-decay tests. Using a vacuum cleaner, a differential negative pressure of approximately 10 cm of H_2O was produced. The time for decay of pressure from 10.0 cm to 5.0 cm H_2O was determined to check gas tightness. A 5 min pressure-decay time being considered as an acceptable level of seal. When gas tightness had been satisfactorily, achieved, the stacks were immediately treated with PH_3 tablets at a dose rate of 1 tablet per tonne.

Data collection

Representative samples of grain were taken at the beginning and end of storage from pre-determined points, namely, from 9 bags in the top-layer, 9 bags in the middle- and 9 bags in the bottom-layer, for quality assessment, including moisture content (m.c.), damaged kernels, insect bored kernels, and foreign matter, and evaluation of insect infestation (Fig. 1).

Gas concentration and temperature determination

During construction of the stacks, plastic tubing for gas concentration monitoring was installed at the top of each stack (Fig. 1). Thermocouple wires for temperature readings were also installed at the top of the stack. Gas concentrations were monitored on the 7th, 15th, 30th and 60th days of storage, while temperatures inside the enclosures were monitored daily at 10:00 a.m., and at 2:00 p.m. Additional monitoring of PH_3 concentrations and temperatures inside the enclosures continued for the 6 months storage period.

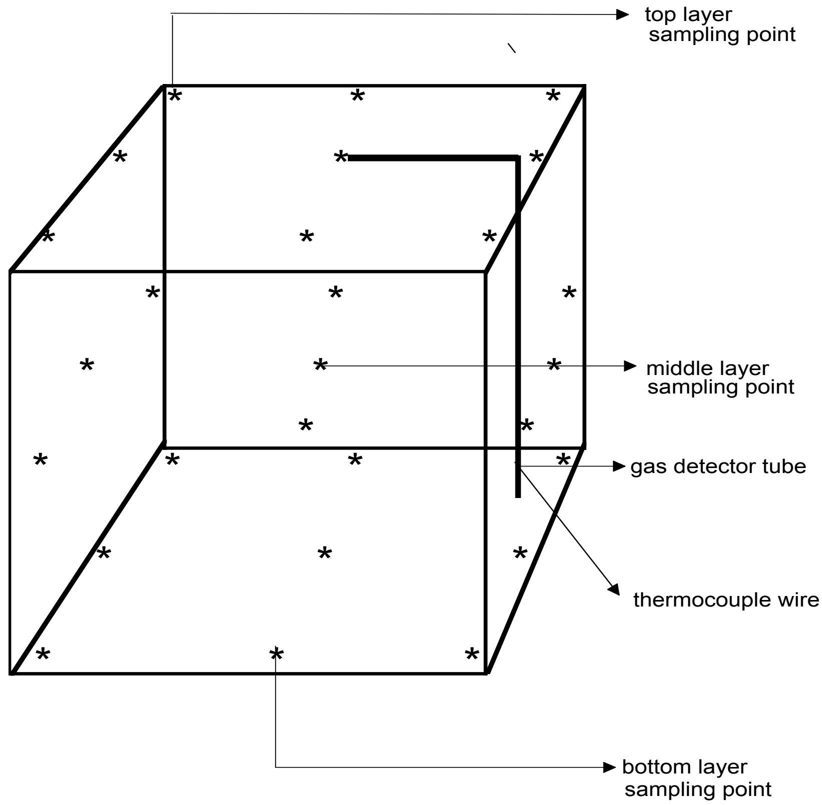

Fig. 1. Gas detector tube and thermocouple wire location and sampling points.

RESULTS AND DISCUSSION

I. Technical evaluation

Physical Analysis

Moisture Content: The average m.c. from all stacks and sampling points as presented in Table 1 was found to be within the maximum recommended level for corn (13.5%) under sealed storage (van S. Graver and Annis, 1994). The recorded m.c.'s ranged from 11.73% to 12.42%. Nevertheless, results of analysis of variance (ANOVA), indicated that there was a significant increase in m.c. over the 6 months storage period. It also revealed that there is a significant difference between the initial and final m.c. readings and between the top, middle and bottom sampling points. To further determine which of the sampling points contributed to this significant difference, Duncan's multiple range test (DMRT), was employed. Results showed that only the final top moisture reading was significantly different from the rest. This can be attributed to the fact that the top portion of the stack was in direct contact with the cover-sheet for six months. Consequently, during this period, condensation within the enclosure may have occurred as a result of moisture migration and the corn grains at the upper surface readily absorbed the condensed water. In a related study conducted in Malaysia by Muda *et al.,* (1987) on sealed storage of milled rice under CO_2, they also revealed a significant increase in m.c. after several months storage. On the basis of initial and final m.c. measurements, they too attributed this increase to moisture absorbed as a result of convection currents.

Damaged Kernels: Analysis of damaged kernels (Table 1) showed an actual decrease. However, when the data were subjected to statistical analysis it was shown that the initial and final counts were not significantly different from each other. This signifies that adequate sealing of the enclosures had protected the corn stocks from harmful agents such as microorganisms, insects, birds and rodents, rain-water, and other factors that lead to grain damage. Results further revealed that the level of kernel damage was not significantly different at the different heights within the stack.

TABLE 1
Comparison of average quality parameters of corn grains stored in three 190.8 tonne stacks under SEFUST at the beginning and end of a 6 month storage period

Parameter	Initial	Final
Moisture content (%)	11.73	12.42
Damaged kernels (%)	4.20	3.64
Insect bored kernels (%)	2.41	2.64
Foreign matter (%)	0.96	0.71

Insect Bored Kernels (IBK): The IBK as a quality parameter in corn quality evaluation is an index of insect infestation, and in a broader context, of the level of cleanliness and sanitation during storage. Grain damage, as a result of insect feeding was determined by calculating the difference in number of bored kernels between the initial and final samples. The study showed that there was a 0.23% increase in bored kernels in the final samples (Table 1). However, analysis of treatment means revealed that this numerical difference was not significant. In consequence it was considered that the well sealed enclosure of the SEFUST technology together with an adequate dose of PH_3 tablets, successfully arrested reproduction and development of insects in all of their life stages, thus providing improved protection for the stored corn.

*Foreign matter***:** Table 1, also shows that the corn stocks used in this study were found to have small amounts of impurities or foreign matter. Although there was a significant decrease in percentage foreign matter between initial and final sampling, this decrease can be attributed to non-uniform distribution of foreign matter within the marked sampling bags.

Insect infestation

Close observations of the stacks under SEFUST were made during the opening of the plastic enclosures. No live insects were seen at the bottom of the stacks and under the pallets immediately after the covers were removed. A small number of dead weevils, *Sitophilus zeamais* (L.), were found on the sides of the stacked bags inside the enclosures. The stacked bags were still clean and dry, which indicated that the stocks had been protected from dust and infestation. These adequately sealed enclosures with PH_3 treatment provided effective disinfestation and provided a high level of protection to the stored grains. This supports the findings of Annis (1990), that grains stored at a safe m.c. and dosed adequately with chemical treatment may be stored for extremely long periods without risking quality deterioration.

Phosphine concentration

The corn grain stacks treated with PH_3 at 1.0 tablet per tonne as recommended by NAPHIRE as the standard dosage requirement for sealed enclosures, registered a maximum gas concentration of 400-600 ppm (Table 2) after seven days exposure. This is comparable to NAPHIRE's data on gas concentrations of 550-700 ppm as reported in Sabio *et al.,* (1991). This exceeds the concentration requirement for PH_3 of 100 ppm (over the exposure period) to achieve total kill of insects present in the enclosure. These results were also superior to those of Donceras *et al.,* (1992) who reported a gas concentration of 60 ppm after 5 days exposure to the normal dosage of 2.31 tablets per tonne used under conventional fumigation. This concentration decay normally occurs in conventional fumigation due to the inadequate seal where sand-snakes or packaging tapes are used to seal the tarpaulins to the floor. The absence of live insects in the sealed enclosures after 7 months of storage can be attributed to the satisfactory gas holding capability of the enclosure because of satisfactory sealing.

TABLE 2

Phosphine gas concentrations during fumigation of corn grains stored in three 190.8 tonne stacks under SEFUST for 6 months

Enclosure	Gas Concentration (ppm)			
No.	day 7	day 15	day 30	day 60
1	600	200	100	below 50
2	400	200	80	below 50
3	600	200	80	below 50

Grain temperature inside the enclosure

The temperature range inside the enclosures was observed to be 31-34°C throughout the storage period (Table 3). Previous studies on SEFUST gave similar results. This is an indicator that no metabolic activities causing heat generation occurred inside the enclosures, since temperature increase is a manifestation of insect population growth or fungal development and ensuing damage to the stored grain.

TABLE 3
Average temperatures of yellow corn grain stored inside three 190.8 tonne stacks under the SEFUST technology for 6 months

Enclosure No.	Temperature °C								
	day 1	day 7	day 15	day 30	day 60	day 90	day 120	day 150	day 180
1	31.5	32.5	33.0	33.0	33.0	33.0	32.0	32.0	32.0
2	33.5	34.0	34.0	33.0	33.0	33.0	33.0	32.5	32.0
3	32.0	33.0	34.0	34.0	34.0	33.0	33.0	32.5	31.0

II. Economic Analysis

Cost analysis (Table 4) showed that there is a difference of PhP 51.6 (at a fluctuating exchange rate of PhP 50 ≈ US$ 1 in 2001) per bag in favor of the SEFUST technology over the conventional storage of corn for a 6 month period. Likewise, storage of 3,816 bags (190.8 tonnes) of corn using SEFUST revealed a much lower cost of only PhP 56,760, whereas it is more than four times more costly (PhP 253,647) when one uses conventional storage over the same period of time.

As regards initial capital investment, SEFUST incurred a higher cost at PhP 17,904 because of the high cost of equipment needed in the initial application such as, plastic enclosure, floor-sheet, vacuum cleaner, gas detector pump, tele-thermometer, thermocouple wires, ladder, etc., compared to the conventional storage which only needed a fumigation sheet, ladder, gas mask, and backpack sprayer computed at PhP 14,838. But for commodities to be stored for a longer period, SEFUST is still advantageous (PhP 12,439) over that of conventional storage (PhP 16,488) because of the savings on some direct costs such as single application of pest control administration, usage of a single chemical, etc. Furthermore, in conventional storage there was a higher maintenance cost of storing corn due to blowing/cleaning operations after six months storage, incurring a 5% weight loss (Sabio *et al.*, 1992) that amounted to PhP 58,037, and the cost of handling during cleaning of infested corn grains at PhP 89,287. This is in contrast to SEFUST where no cleaning or blowing of corn stocks was required from the start of storage until disposal of the stocks. SEFUST also incurred losses during storage but these were minimal and can be attributed to spillages during handling operations. Based on the study itself, the established weight loss due to storage for a six months period using SEFUST was 0.213%, with a monetary value amounting to PhP 26,416 whereas the cost of weight loss due to storage and or insect infestation for conventional storage is valued at PhP 74,994.

When the project was started, the corn stocks that were used in the study were procured at a buying rate of PhP 6.50/kg. After six months in storage, the stocks under SEFUST were sold at a selling rate of PhP 6.65/kg. Considering the quality of stored corn, the SEFUST technology is clearly a better alternative for preserving stocks compared with conventional storage where the price of corn stocks after six months of storage could not be forecast.

TABLE 4

Comparative cost analysis of conventional storage practice and SEFUST using phosphine as a fumigant for 3,816 bags of corn stored for six months (in PhP = Philippine Pesos)

PARTICULARS	CONVENTIONAL STORAGE	SEFUST
I. DIRECT COST		
A. Variable Cost		
1. Labor		
-Fumigation/SEFUST	3,216.54	7,266.54
-Spraying	4,633.08	0.00
2. Gas filter	2,500.00	0.00
3. Hand gloves	840.00	0.00
4. Pesticides	720.00	0.00
5. Fumigant	4,579.20	763.20
6. SEFUST materials & supplies	0.00	4,410.00
Sub-Total	**16,488.82**	**12,439.74**
B. Fixed Cost		
1. Depreciation	8,820.00	12,240.00
2. Insurance	536.25	684.75
3. Repair & Maintenance	3,900.00	4,980.00
Sub-Total	**14,838.75**	**17,904.75**
II. INDIRECT COST		
Losses due to insect / storage	74,994.89	26,416.28
Losses due to blowing/cleaning	58,037.04	0.00
Cost of handling during cleaning	89,287.75	0.00
Sub-Total	**222,319.68**	**26,416.28**
III. TOTAL STORAGE COST	**253,647.25**	**56,760.77**
IV. STORAGE COST PER BAG	**66.47**	**14.87**
V. GAIN WITH THE USE OF SEFUST		**51.60**

CONCLUSION

This study on the storage of yellow corn grains under the SEFUST technology using PH_3 fumigation was satisfactory in terms of its effective control of infestation and prevention of reinfestation. The use of SEFUST with PH_3 can be considered an alternative treatment for indoor protection of grains, specifically corn, for a longer storage period. It can be noted that both the total absence of insects and the preservation of quality after six months revealed the technique to be a better pest control method compared to conventional fumigation practice. It shows that under local conditions the technology can be operational and economically feasible.

Furthermore, based on the actual implementation of SEFUST, bidders/buyers commented that with the NFA's adoption of SEFUST, the agency will be able to dictate the price of corn because the quality of stocks remain the same even after prolonged storage, unlike the previous situation where corn being offered to bidders had already deteriorated or had signs of infestation after several months in storage.

RECOMMENDATION

With regards to the socio-economic aspect, information related to the management and programming of stock disposition/distribution should be taken into consideration, namely the volume of stocks to be stored using SEFUST should be determined by undertaking a sound forecasting of grain procurement and distribution, that will serve as a basis for the selection of the most appropriate method to be used. This in turn will aid in determining specific geographical locations for long term safekeeping of grains. The Sealed Enclosure Fumigation Storage Technology (SEFUST) should not be looked upon as an all-inclusive pest control method. Its operation must always be complemented with good storage practice, particularly a high degree of hygiene and rodent control to ensure its success.

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