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CARBON DIOXIDE FUMIGATION OF ORGANIC GRAIN FOLLOWED BY 'REFRIG-AERATION'

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ABSTRACT

Organic grain was fumigated on arrival in storage with carbon dioxide (CO_2). Concentrations were held above 30% for 15 d by continuously topping up with additional CO_2 through a recirculation system. Subsequent aeration with refrigerated air enabled long-term storage without the need for re-fumigation. This integrated commodity management strategy provided the means to outload 60-t batches of insect-free grain over a total storage period of 24 months. The results of insect trapping in the storage area are discussed, and the equipment and operational costs of implementing this strategy are described.

INTRODUCTION

Grainco (Queensland, Australia) specialises in storing grains in a sub-tropical to tropical environment. Clients include the Australian Wheat Board, flour mills, feed mills, brewers and growers. The greatest challenge in accomplishing this task has been to prevent damage caused by stored-grain insects. In the 1970's, grain was protected in Queensland by admixture of residual grain protectant insecticides and by aeration. These strategies are no longer employed due to the development of insect resistance to protectants and, more particularly, to consumer demand for low (or zero) chemical residue food. They were replaced during the 1990's by sealed storage and the use of fumigants.

The increased demand over the past decade for clean, "green" food has provided the challenge to develop commercially viable strategies for storage of large bulks of grain in hot humid environments without reliance on chemicals (fumigants or residual pesticides). The technology of grain disinfestation with controlled atmospheres (CA) using nitrogen

(N_2) or carbon dioxide (CO_2) has been well-researched (Boland, 1985; Hoey, 1981), and suitable procedures are readily available (Bond, 1989; Annis and van S. Graver, 1989; Banks and Annis, 1977).

Grainco (like its predecessors, the State Wheat Board and Bulk Grains Queensland) has been actively involved in developing this research into viable commercial grain protection strategies. Trials carried out in the past (Boland, 1985; Hoey, 1981) centred on large bulks in gastight steel or concrete bins. The large tonnages involved provided some economy of scale to spread costs. However, whereas in an export situation larger storage structures are preferred and the entire contents are out-turned for delivery once disinfested, for the domestic grain market the situation is more demanding. Mills require reception of grain a truckload at a time, so the grain must be drawn from the same bulk over a period of 18 months or more. This requirement, in itself, adds a significant new dimension to the challenge of providing insect-free storage in a chemical-free environment.

To achieve this level of control, grain needs to be disinfested as soon as possible after intake. In the case reported here rejection of infested deliveries was not an option. Once disinfested, the challenge to keep the grain insect-free could theoretically be met by aeration (Bridgeman and Collins, 1994; Navarro and Calderon, 1980; Hunter, 1981). Unfortunately, in Queensland, the period when grain is delivered into storage coincides with hot, humid climatic conditions. These are the optimal conditions for insect population development, and there is only a very short period during the day when conditions are suitable for aeration with ambient air. For this reason an air conditioning system ("refrig-aeration") was used to aerate the grain.

The concept of cooling grain with refrigerated air had been applied previously by Grainco (Taylor and Elder, 1981) but was not extended due to the energy costs of the operation. In earlier successful trials, the process resulted in uninfested grain. In the case reported here, it was considered that the extra cost involved in pulling the grain temperature down to below 9°C in order to disinfest it would be unnecessary if the aeration process was used in an integrated plan with another process, namely a CA treatment.

The client was 'Daydawn', a manufacturer of organic breakfast cereal. Its requirement for an uninterrupted periodic out-turn of insect-free, organic grain in small tonnages was achievable in theory. The bins would be protected from reinfestation by climatic manipulation. There would be no need to re-gas bins when only partly full. Most importantly, none of the planned strategies would compromise the organic nature of the product.

METHODS AND MATERIALS

The client

The client requested Grainco to store its supply of organic wheat for 18 months or longer so that this new line of business could be established. 'Daydawn' wished to draw on the stocks on an "as required" basis, stipulating that they be insect-free and that the organic status of the grain not be compromised. The organic nature of the product was expected to command a premium in the market.

The grain

The grain (1,000 t of premium quality wheat) was delivered from on-farm storage. It was graded and checked for organic authenticity prior to intake. Only grain grown by properties certified by the organic authorities and produced by sustainable farming practices without assistance from artificial chemicals was acceptable. Growers were paid a premium for the grain. However, on reception most of the deliveries (70%) were found to be infested.

The plan

In theory, the plan was to disinfest the grain completely by CA treatment with CO_2 within 2 weeks of delivery. After a 15-d exposure period, aeration with refrigerated air ("refrig-aeration") would be used to reduce the temperature of the grain to below 20°C (ideally 15°C). This would effectively prevent insects from recolonising the grain and prevent subsequent population growth. Periodic inspection of the grain would verify the success of the procedure.

The storage

The Haunstraup multi-bin complex at Grainco's Malu depot near Toowoomba, Queensland, was selected for the trials. This complex consists of a single 1,600-t capacity cell which is surrounded by eight 500-t bins. The complex was selected because of its central location and the multiple segregations that it offered. The bins used were 600-m^3 concrete structures with conical bases, each with a storage capacity of 510 t premium grade wheat. The bins were constructed in the 1950's, and none of them conformed to standard pressure tests (Banks and Ripp, 1983). The two bins to be used (bin Hm205 and Hm206) were sealed on the cone and lower walls and at the roof to wall junction. Three-metre lengths of 35-cm half-round perforated ducting were installed down the cone to facilitate the CA fumigation and aeration. The bins were pressure tested for pressure decay from 100 to 50 mm of water gauge at 3 and 2 min, respectively.

The major leakage was from longitudinal cracks in the concrete walls. This level of airtightness would disqualify the bins from the traditional static type fumigation.

The CA fumigation system

"BOC Gases" supplied CO_2 as a liquid in pallet tanks. The CO_2 was delivered via a vaporiser to the bin recirculation system. A "3b Dawn" fan powered the recirculation through the ducting described above. Gas sampling lines were located in the base of the bin, at the grain surface and in the ducting. Because of the leaky nature of the bins, a continuous-addition system was set up to maintain the concentration above the target concentration of 30% for 15 d.

The refrig-aeration system

The refrig-aerator was set up to cool both bins simultaneously. The power usage of the unit was approximately 31 kw/h. The cost of power was AU$ 0.115 per kw/h. During the initial cooling phase, the unit operated for 20 h per day. Once the cool front had moved through the grain and stabilised (5 d), the aeration time was reduced to a maintenance phase of 2 h per day during summer and 1 h per day during winter. The target was to achieve a grain temperature of about 15°C.

Population monitoring

After the CO_2 fumigation had been completed, a composite grain sample of 3 kg was taken from the bulk of each bin and monitored monthly to detect any insect development. These samples were stored at ambient conditions for 6 months. The grain was also inspected monthly when it was turned in the bin, and average grain temperatures were measured at the same time. The grain was finally inspected for the presence of insects on out-turn before delivery.

RESULTS

General

The planned process was successful. No insects were detected in either of the two test bins during the 24-month storage period although large populations of insects were detected in silos adjacent to the test bins and in facilities close by.

Controlled atmosphere treatment

The CO_2 concentrations recorded during the CA treatment were plotted on a daily basis (Fig. 1). It can be seen from the figure that the target dose could only be maintained by continuous topping up. This procedure enabled the treatment to be carried out successfully. Had the bins been properly sealed, however, only about half the gas would have been required. The approximate cost of CO_2 treatment, including labour and gas, was AU$ 2/t of grain.

"Refrig-aeration"

The grain temperature was monitored at the silo base once a week and also once a month during bin-turning activities. The readings were tabulated against weekly minimum and maximum ambient temperatures. The number of fan hours per week was also recorded (Fig. 2). The refrig-aeration unit operated on a timer. This made costing the process very straightforward. The cost of cooling was approximately AU$ 1/t/month over the 24-month storage period.

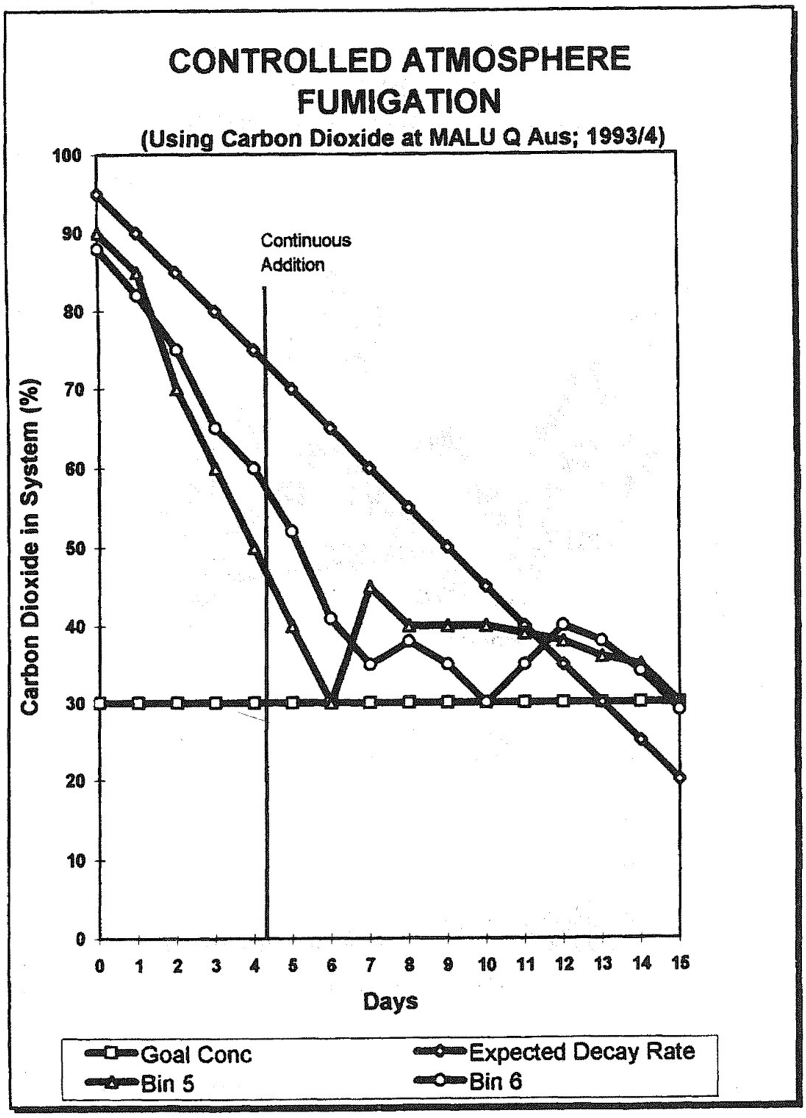

Fig. 1. CO_2 concentrations during the initial CA treatment of organic wheat.

Insect population monitoring

No insects were detected in the bin samples taken at post-harvest reception into storage (and disposed of after 6 months of checking), nor were insects detected during monthly bin-turning activities of the test bins though insects were detected in other bins within the complex, on the grain path outside the bins and in the surrounding areas. No insects were detected in loads of grain on out-turn for delivery.

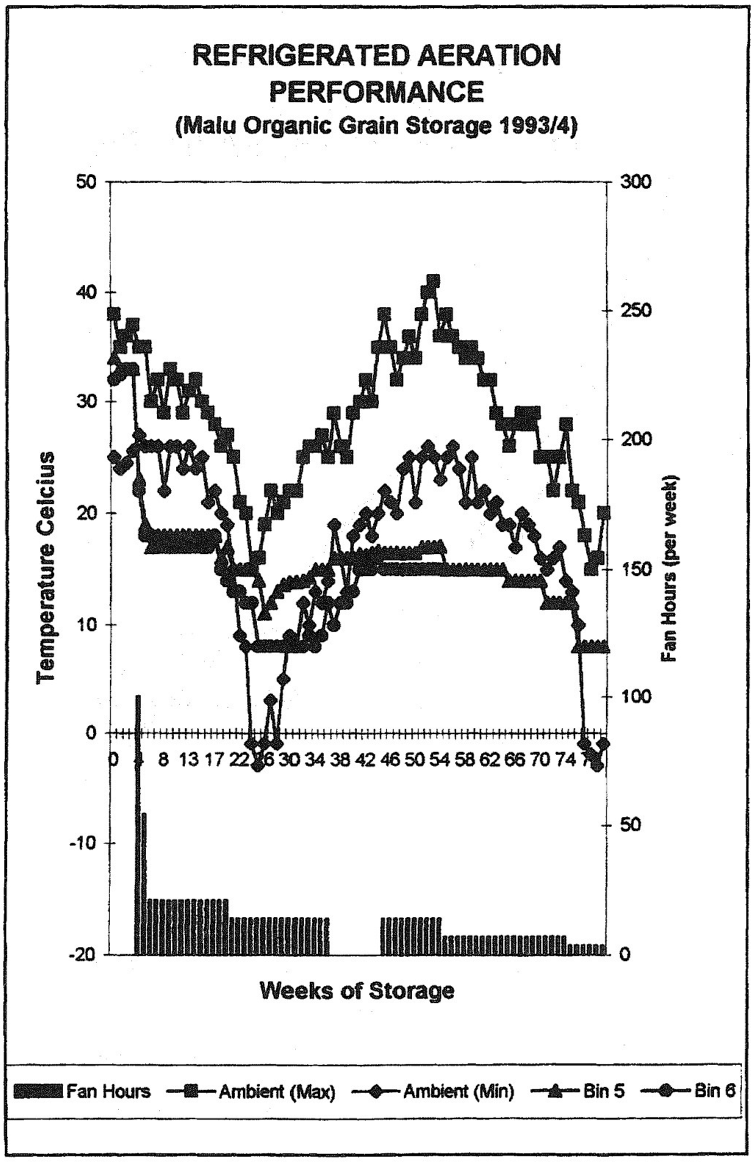

Fig. 2. The refrig-aeration performance as indicted by weekly measurements of grain temperature and weekly readings of fan hours.

Costs

The actual costs of the full grain protection process in this project are deemed commercially sensitive and have therefore been omitted from this paper. The approximate costs were about four times those of periodic tri-monthly fumigation with phosphine (PH_3).

DISCUSSION

The success of this process has led to additional clients who are looking for organic grain storage. There is, however, scope for significant improvement. The cost of the operation, although significantly higher than that of PH_3 fumigation, still appeals to clients seeking a chemical-free storage environment. The ability to maintain continuous, periodic out-turn is also a significant service. Although the costs are apparently acceptable to the clients who want to store a special commodity, they can be substantially reduced. Both the CA and the refrig-aeration process can be improved on. Improvements in the bin sealing, for example, would halve the amount of CO_2 used.

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