THE USE OF CARBON DIOXIDE FOR QUALITY PRESERVATION IN SMALL SHEETED BAG STACKS

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Abstract: Successful trials of the combined use of carbon dioxide and well sealed flexible PVC sheeting for insect control in 100-200 t stacks of bagged cereal products have been reported elsewhere. For smaller stacks, the surface area to volume ratio is increased, and effective gas concentrations may be more difficult to maintain. A trial carried out in Lae, Papua New Guinea, showed that the method was suitable for smaller stacks (10-20 t). An average concentration of > 90% CO_2 was obtained by adding approximately 4.0 kg of carbon dioxide per tonne of commodity. The loss rate constant of CO_2 from the enclosed gas was between 0.012 and 0.025 day^{-1} in the three stacks treated. The treatment helped preserve the quality of green coffee beans in this hot and humid environment, where rapid degradation normally occurs if this commodity is stored in open stacks.

INTRODUCTION

Insect control in bag stacks of stored products may be thought of as having two phases; disinfestation and prevention of reinfestation. Both of these operations present difficulties in bag stacks. Disinfestation is usually carried out by fumigation with either methyl bromide or phosphine under 'gasproof sheeting'. This sheeting is typically a plain sheet of PVC or polythene draped over the stack and sealed to the floor using long, heavy and flexible weights, e.g. 'sand snakes' or chains. Usually, no attempt is made to establish the level of gastightness other than a visual inspection for obvious leaks, accompanied occasionally by testing for detectable concentrations of fumigant outside the enclosure.

Enclosures formed in this fashion may be significantly leaky even when apparently well sealed (Annis *et al.* in press). This leakiness may lead to areas of low fumigant concentration and consequently an imperfect fumigation.

Conventionally, the cover is removed after fumigation, and the stack is consequently exposed to possible reinfestation. Prevention of reinfestation is usually attempted by a combination of store hygiene, application of pesticide to the outer surface of the stack by spraying and general fogging of the storage environment with pesticides. Such measures are often unsuccessful and may lead to the need for repeated fumigations.

A treatment consisting of fumigation under a substantially gastight enclosure followed by prolonged storage within this 'insect proof' enclosure should reduce the number of operations involved in protecting the product from insect damage when stored for long periods. To avoid degradation of quality in such an enclosure, it is essential that any insect infestation must be eliminated shortly after the enclosure is sealed. Insects, apart from causing physical damage to the product, may cause localised increases of heat and moisture which could lead to levels of these factors which are conducive to mould growth, with consequent quality degradation and risk of mycotoxin formation.

There should be only a small change in the total amount of water contained within the enclosure during the storage period, provided that all insects are killed, and the product is dried to a level at which its endogenous respiration is low (Oxley 1948). Furthermore, if diurnal and seasonal temperature variations are not great, the water activity within the stack will not change significantly and there should be little risk of liquid water forming ("sweating" or condensation). Where a product is drier than the equilibrium moisture content of the ambient air, a well sealed enclosure may offer a partial barrier to moisture ingress. This is especially desirable when the contained atmosphere is occasionally flushed out with a dry gas.

Accordingly, a trial was set up at Lae, Papua New Guinea (PNG), in collaboration with the PNG Coffee Industry Board, to determine whether high grade green coffee beans could be stored without deterioration for prolonged periods in sealed sheeted stacks in a coastal area where the relative humidity is normally high. Under normal storage conditions (unsheeted bag stacks) in these areas, high quality coffee beans suffer substantial quality degradation after only a few weeks of storage. A further aim of this trial was to show that the process designed for large stacks (100 - 200 t) (Annis *et al.* in press) was applicable to stacks in the 10 - 20 t range.

METHOD

The trial was conducted in a well ventilated, corrugated iron warehouse normally used to store a wide range of products not usually liable to infestation. While the trial was in progress, there was an infestation of *Tribolium castaneum* (Herbst) in some stacks of chicken feed held in the warehouse. Routine insect control measures were not carried out in the warehouse during the course of the trial.

Two stacks each of approximately 18 tonnes of green coffee beans (1 stack *Coffea robusta*, and 1 stack Y grade *C. arabica*) and one stack of approximately 9 tonnes (mixed *C. robusta* and *C. arabica*) were built on thick (0.76 mm) polyvinyl chloride (PVC) floor sheets. All the stacks were found to have a moderate infestation of *T. castaneum* and larval *Ephestia* sp. when they were enclosed.

THE ENCLOSURE

The stacks were enclosed within tailored fumigation enclosures made of nylon-reinforced, PVC sheeting (Wavelock 41), and the outer edge of each enclosure was bonded to the edge of the PVC floor sheet with a urethane sealant. After checking the enclosure for obvious leaks, a small vacuum cleaner was connected to the gas inlet pipe built into the enclosure to create a negative differential pressure of about -1500 Pa (15 cm water gauge) with respect to atmospheric pressure. The inlet was then sealed and the pressure change over time recorded (see Annis *et al.* in press, for a detailed account of sealing and pressure testing such enclosures). The decay from -500 to -250 Pa took 11, 10 and 7 minutes for stacks 1, 2 and 3 respectively. The pressure test standard for a carbon dioxide (CO_2) treatment using a single gas addition to disinfest a full, rigid sealed structure with a capacity between 300 and 10 000 t is 5 min, for a halving of differential pressure (Banks and Annis, 1980).

GAS INTRODUCTION AND INITIAL GAS HOLDING

In all stacks, CO_2 was added as 'snow' obtained from 30 kg cylinders of food grade gas fitted with eductor tubes. The 'snow' was piped so that it would spread between the timber layers of the base pallets and sublime without contacting the lower bags. Carbon dioxide was added to each stack until the gas leaving an exit vent made in the top of the stack contained > 90% CO_2. The enclosures were then completely sealed. The introduction process used between

60 and 70 kg of CO_2 (2-2.3 cylinders) per 18 t stack less than 45 kg (1.5 cylinders) for the 9 t stack.

At 20°C, the regime required for successful insect control is an initial CO_2 concentration above 70% and a concentration above 35% for > 10 days (Banks *et al.* 1980). All three stacks maintained a concentration of above 35% CO_2 for longer than 25 days, and had CO_2 loss rate constants 0.024, 0.012 and 0.025 day^{-1} for stacks 1, 2 and 3 respectively.

RESULTS AND DISCUSSION

The stacks were opened after 26 weeks of sealed storage and the coffee and the others areas of the enclosed stacks were found to be free of insects. The coffee in stacks 1 and 2 was judged by local graders to have maintained its high quality, and had not suffered any of the humidity-related damage expected when coffee is stored in the humid coastal areas for more than a few weeks. The contents of stack 3 had suffered significant moisture damage, as evidenced by "caking" in the top two rows of sacks and a "distinct off odour". The timber pallets used for the base of this stack were saturated with water when the stack was made, while those used for the other two stacks were dry. This was the only difference noted in the treatment of this stack from the other two, and may have been partially responsible for the moisture problems.

All bags and stack covers were free from rodent damage when they were unsealed despite the presence of many rats in the warehouse. The level of rodent infestation was clearly high because there was substantial rodent damage to many of the outer bags in all of the test stacks within 2 days after they were uncovered. This observation suggests that the sealed and treated enclosures on this occasion offered the product some protection against rodent attack.

CONCLUSION

This trial demonstrated that a well sealed, flexible PVC enclosure combined with a CO_2 treatment can be used to disinfest stacks of bagged product as small as 9 tonnes. The enclosure's "insect proofness" is such that it appears to give long term protection against reinfestation. The treatment also offers a barrier to the damaging humidity normally found in coastal, tropical areas, and allows prolonged storage of products normally damaged by this type of environment. The method is sensitive to faults in operation, and additional research is required before many of the problems encountered can be evaluated and corrected and the technique recommended for routine storage.

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