Donahaye, E.J., Navarro, S. and Varnava, A. [Eds.] (1997) Proc. Int. Conf. Controlled Atmosphere and Fumigation in Stored Products, 21–26 April 1996, Printco Ltd., Nicosia, Cyprus, pp. 89–93

RAPID DISINFESTATION THROUGH THE COMBINATION OF CONTROLLED ATMOSPHERES AND HEAT

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ABSTRACT

The suggested phaseout of methyl bromide production and use in industrialised countries by the year 2010 increases the need for alternative rapid disinfestation methods. High temperatures increase the metabolic rates of insect pests and thus enhance the lethal action of both fumigants and Controlled Atmospheres (CA's). Experiments with the granary weevil *Sitophilus granarius* indicated that treatment with carbon dioxide (60% CO_2 and 40% air or 90% CO_2 and 10% air) or nitrogen (98% N_2 and 2% O_2) over 46 d or 77 d, respectively, provided complete control at 10°C. This could be reduced to 8 d at 35°C and 1.5 d at 40°C for all tested atmospheres. Therefore, such valuable products as nuts, herbs, tobacco or spices, which can tolerate such temperatures without loss of quality, could be rapidly disinfested by either of these two CA's. The results at 40°C also indicate that empty room treatments are feasible by a combination of CA's and heat in sufficiently gastight structures. Moreover, the data indicate that CA's hold special promise in dry warm climates where the stored-product temperatures are naturally high.

INTRODUCTION

During its meeting in Vienna in November 1995, the United Nations committee on ozone depletion agreed on a phase-out of the production and use of methyl bromide (MB) in industrialised countries by the year 2010 (Mueller, 1996). The implementation of this decision will further reduce the number of fumigants available for pest control. The rapid toxic action and cost efficiency are two of the reasons why the loss of MB would leave a gap not readily filled by other fumigants. For each MB usage the most suitable alternative treatment needs to be found. If such stored products as grain, herbs, tobacco, nuts or cocoa beans must be regularly disinfested within short periods of time in order to meet quarantine regulations, treatment with carbon dioxide under high pressure (10–40 bars) may be one possible alternative (Prozell and Reichmuth, 1991). However, such a treatment necessitates moving the infested goods, thus spreading the risk of infestation to all transportation equipment used; furthermore, the pressure-tight steel chambers needed for such treatments are quite costly. Another possible alternative is the acceleration of the lethal action of phosphine (PH_3) by the use of quick-releasing formulations, the application of a ready-made gas supply, or combination with carbon dioxide (CO_2) and/or increased temperatures (Desmarchelier and Wohlgemuth, 1984; Mueller, 1994).

CA's of low oxygen (O_2) and/or high CO_2 concentrations are only slowly gaining importance because of both the high standards of gastightness required and the relatively long exposure times needed at ambient pressure and temperature.

In this paper the effects of grain temperatures from 10°C to 40°C on the efficacy of three different CA's are presented. The laboratory study was carried out to determine the effects of various ambient temperatures on the time needed for disinfestation, as well as to determine how much it would be possible to reduce exposure periods lethal to the rather tolerant grain pest *Sitophilus granarius* by using a combination of CA's and heat.

MATERIALS AND METHODS

To study the effects of gas mixtures on developmental stages of defined age, the following insect culture method was used: at 25 ± 1°C, 75 ± 5% r.h., approximately 2500 young adult granary weevils were placed on 142 g of fresh uninfested wheat for an oviposition period of 3 d. This culture technique was repeated weekly to obtain the following five juvenile stages for use at the start of each experiment: stage 1: eggs 1–4 d after oviposition; stage 2: young larvae 8–11 d after oviposition; stage 3: larvae 15–18 d after oviposition; stage 4: old larvae 22–25 d after oviposition; stage 5: mainly prepupae and pupae 29–32 d after oviposition.

Details of this procedure are given in Adler (1991). For each juvenile group, 70 kernels of infested wheat were placed in a wire mesh cage.

These samples plus an additional sample with 50 adult weevils on uninfested grains were all transferred into a 2.3-L Dressel flask. Then the efficacy of the following gas mixtures was tested at 10, 15, 20, 25, 30, 35 and 40°C using five different exposure times for each experiment: (1) 98% N_2, 2% O_2; (2) 60% CO_2, 32% N_2, 8% O_2; and (3) 90% CO_2, 8% N_2, 2% O_2 (% by volume).

The gas mixtures were prepared manometrically prior to the experiment (details in Adler and Reichmuth, 1988). Five Dressel flasks (to be held for five different exposure times) were connected by PVC-tubing in a climatised chamber and flushed with the experimental gas mixture until the measured O_2 content matched that of the particular experimental gas mixture. The experimental gases were humidified to 75% r.h. using a saturated sodium chloride solution (Winston and Bates, 1960) before being flushed through the experimental vessels. After purging, the flasks were closed for the desired exposure period. When the flasks were opened, O_2 content was again determined. The insects were held at 25°C, 75% r.h., and they were checked weekly for adult emergence from the juvenile stages and adult mortality, respectively.

RESULTS AND DISCUSSION

The experiments revealed the paramount influence of temperature on treatment time. Exposure times needed to kill all stages of the granary weevil are given in Fig. 1. At all tested temperatures, 60% CO_2 and 90% CO_2 produced almost identical results.

The susceptibility of stages decreased in the following order: (1) 98% N_2, 2% O_2 mixture: adults, eggs, young larvae, old larvae, pupae; (2) mixtures containing CO_2: adults, young larvae, old larvae, eggs, pupae.

As the temperature increased the difference in susceptibility of the different developmental stages was reduced. At exposure times of more than 1 week the residual O_2 content dropped, especially in the flasks treated with the N_2 gas mixture. This can be attributed to O_2 consumption by the insects. At 25°C and below, significantly shorter exposure times were needed for complete control using atmospheres containing CO_2; above 25°C the difference between anoxic and hypercarbic gas mixtures was negligible.

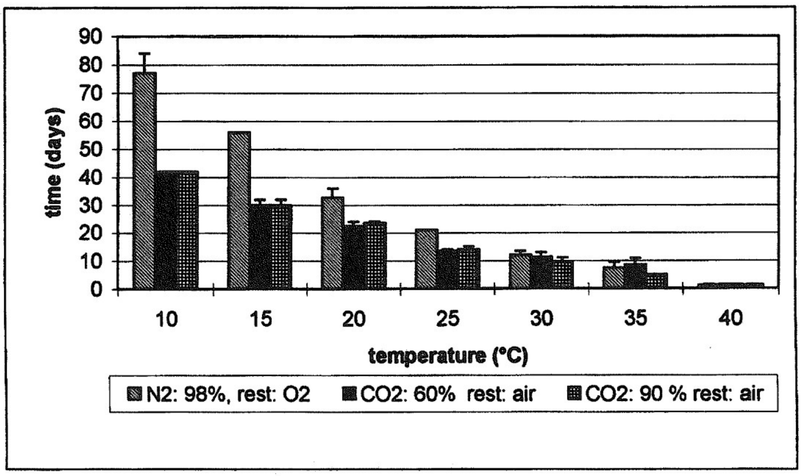

Fig. 1. Exposure times needed with various CA's at different temperatures for complete control of adult and 100% reduction in emergence of juvenile *S. granarius*.

In warm climates, commodities could be effectively treated at temperatures around 30°C within 10 d or less, depending on the pest species present. Under these conditions, increased respiration rates of all living organisms present might even allow for continuous hermetic storage under hypoxic conditions, provided that stored-product moisture contents are low, thereby minimising the risk of condensation. Moreover, shorter exposure times at increased commodity temperatures may render CA's feasible for in-transit treatment on ships sailing from warm climates. In some cases it may even be economically feasible to heat, treat, and then cool down valuable products before long-term storage or transportation.

At 40°C an exposure time of 36 h was sufficient for complete control with all three tested gas mixtures, whereas pupal stages of untreated samples survived exposure to 40°C for 48 h. This corresponds to the data of Jay (1987), who exposed mixed ages of *S. oryzae* to an atmosphere of air and 78% CO_2 or 91% CO_2, respectively, at 55% r.h. At 38°C, 48 h were required for complete control with both atmospheres, and at 43°C similar results could be achieved within 16 h. Thus, given a sufficiently gastight structure, high summer temperatures with some additional heating could be used for empty-room treatment with CA's, in exposure times comparable to those required for fumigation with such toxic fumigants as MB.

The treatment of grain storages with CA's is always more expensive than a MB fumigation (and often more expensive than a PH_3 fumigation). However, under certain conditions, the use of CA's may be more economic and more convenient than the use of a toxic fumigant. In the Berliner Hafen und Lagerhausgesellschaft (BeHaLa), Berlin Westhafen, about 20 concrete silo-bins are located in a building dating from the 1940's. Although these silo-bins are generally not very gastight, two of them were constructed for fumigations with cartox (CO_2 and ethylene oxide). They achieve a pressure half-life of 60–120 sec. According to the storage keeper, in these silo-bins grain treatment with 70% CO_2 for 3 weeks at 20°C costs approximately 3 DM per t, whereas PH_3 fumigation would cost 5 DM per t. Moreover, during CA treatment work can proceed in the vicinity of the treated silo-bin, whereas during fumigation an entire section of the building would have to be shut down. In Germany the local authorities responsible for workers' safety and emission control must be notified before treatment with toxic fumigants, but such notice is not necessary if CA's are used.

In conclusion, a multitude of factors may influence the decision for or against the use of CA's. Today, however, it seems that this technique will be used more frequently in future and that the combination of CA's and heat may be one way to achieve shorter treatment times.

ACKNOWLEDGEMENTS

The author is indebted to Silvia Krause for excellent technical assistance. He also thanks Christoph Reichmuth for reviewing the manuscript.

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