DISINFESTATION OF WHEAT IN AN HARBOUR SILO BIN WITH AN EXOTHERMIC INERT GAS GENERATOR

Francis Fleurat Lessard and Bernard Fuzeau
Laboratoire de recherches sur les insectes des denrées
I.N.R.A. - Centre de Recherches de Bordeaux - B.P. 131
F 33140 Pont de la Maye - France

Controlled atmospheres are yet considered as one of the promising residue-free alternative methods to control storage pests. Field tests on cereal insects demonstrated the practicability of different means of production of controlled atmospheres in practice :

- The use of carbon dioxyde is recommended by JAY and PEARMAN (1971).

- The use of nitrogen is prefered by SHEJBAL *et al* (1973) in Italy.

- The use of hermetic sealing or enclosure of wet grain without gas(es) is commended by RICHARD MOLARD *et al* (1980).

After the review of LE TORC'H (1983) on tolerance of insect pests of stored products in atmospheres of carbon dioxyde or nitrogen gas, the advantages in the use of carbon dioxyde are demonstrated mainly under low temperature. Carbon dioxyde can be used to lower the oxygen content of the normal air with much more facility than the volatile nitrogen and CO_2 gives in addition a benefic anaesthetic effect on insects.

Purging a bin of wheat with a mixture of nitrogen and carbon dioxyde to set a low oxygen tension letal to insects has been experimented principally by NAVARRO *et al* (1979) and STOREY (1975) at a small pilot scale with an exothermic inert atmosphere generator. This last author showed that with low CO_2 content in nitrogen produced by the generator (9 to 9.5 p. cent) the hidden infestation of the weevils is killed only after an exposure time near four weeks at the relatively high temperature of 27° C.

The purpose of this study was to investigate, with a low temperature of the grain in winter, the relative effectiveness of a fumigation like procedure with an exothermic inert gas generator connected to a very large bin of wheat and drived under automatic control.

The experimentation has been designed in natural storage conditions of a french harbour silo in a concrete bin of 2 500 tons capacity, initially adapted for fumigation procedures, with a new sealing paint applied inside.

MATERIAL AND METHOD

Young adults of *Sitophilus granarius* (L.) reared on soft wheat at 25° C and 75 p. cent r. h. were used to infest samples of wheat. A few days after the beginning of adults emergency of the second generation in the cultures, adults were removed by sieving the grain. The infested grain was divided with a Boerner type divider in samples each of 80 g of wheat and put into small aerated plastic containers. In this cages, 100 new adults were added. For each exposure time in the controlled atmosphere, and for each location, four replicates were supplied. All replicates were set at the same time at the top and the bottom of the bin of wheat. (fig. 1).

* mention of the name of the constructor does not involved the author responsability.

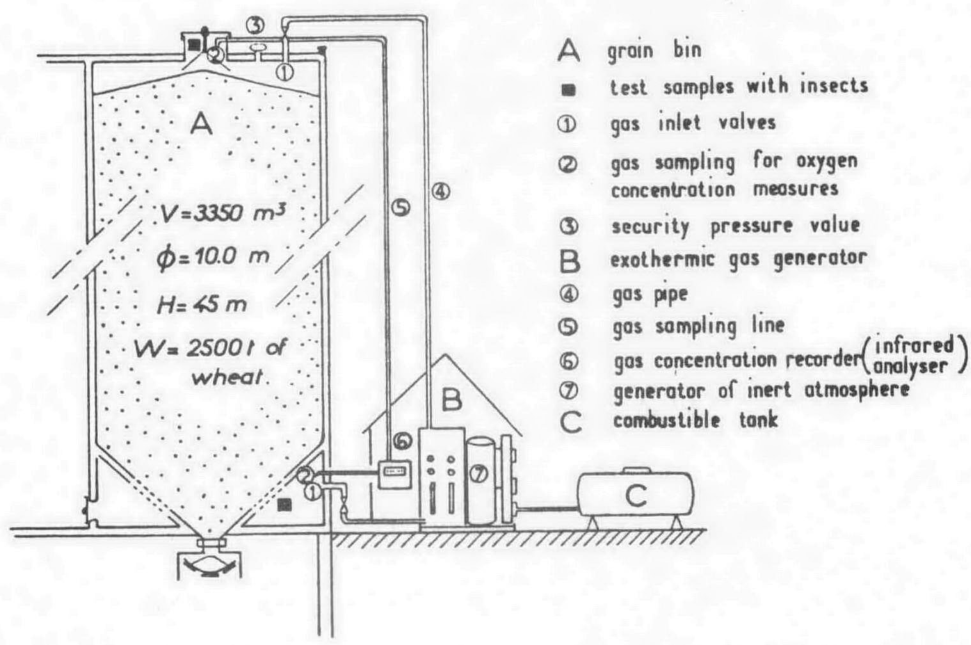

Fig. 1 - 2500 tons concrete hermetic silo equiped with an exothermic inert gas generator. Plant scheme with an indication of the location of the insects samples put inside the silo.

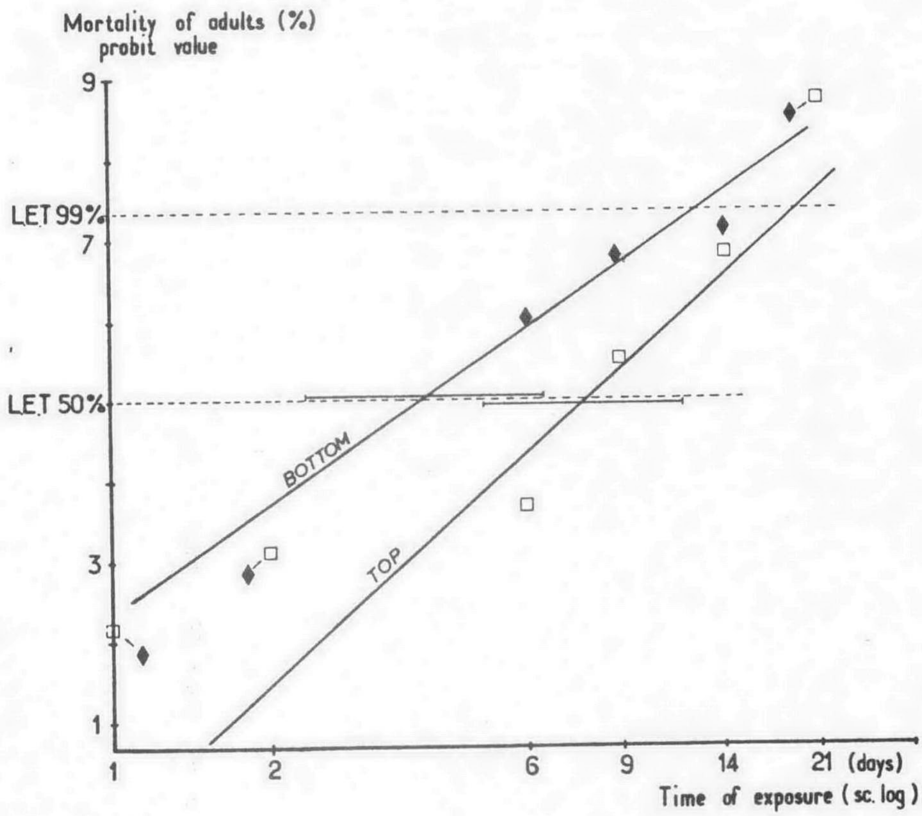

Fig. 2 - Mortality rate of *Sitophilus granarius* adults in a wheat silo at a top and the bottom layer of grain over a 3 weeks exposure period in inert atmosphere produced by an exothermic generator (grain temperature : 10-12° C, gas temperature 7-9° C and oxygen tension between 0,9 and 1,3 p. cent).

After each exposure time of 1, 2, 6, 9, 14 and 21 days, a batch of four replicates was taken out from the two locations. A control batch of wheat infested samples was kept in a rearing room of the laboratory at the same temperature than inside the bin for comparizon.

One day before the beginning of the experiment, the bin was purged with inert gas produced by a burner built by Stein Combustion Europe. The flow rate of generated inert atmosphere was about 150 m^3/h of a gas that usually contained less than 0.5 p. cent O_2, 11 to 12 p. cent CO_2 and 86-87 p. cent N_2 with a small amount of H_2 and CO. During the purge, the injection is made only at the inferior part of the bin.

The gas supply was controlled by an infra-red analyser connected to a line of sampling.

After the concentration at the top is reached with continuous working of the burner, the induction of a new injection is subordinated to a calibrated working pressure at the outlet valve. (fig. 1).

The residual content of O_2 in intergranular space was maintained between 0.9 and 1.8 p. cent.

The samples removed after each exposure time in inert gas atmosphere were sieved to see the mean percentage of dead adults. Afterwards, the samples were kept in a rearing room at 25° C and 75 p. cent r. h. and sieved again two times a week to see emergency of new adults, which were the hidden stages during the treatment. The period of survey lasted over seven weeks for the obtainment of 95 p. cent of the hidden infestation into adults.

The comparizon to the reference sample was done for calculation of the balance percentage of mortality used to fit the log-probit regression line.

RESULTS AND DISCUSSION

Results with adults (table 1) showed that the mortality is achieved only during a 21 days exposure in a weak oxygen tension. The critical level of 99 p. cent mortality was obtained earlier at the bottom of the bin (13 days) than at the top (20 days) (fig. 2). This difference seems to be related to the location of the top samples in the loading system.

table 1 - Mortality rate of the granary weevil adults set inside a 2500 tons wheat bin maintened at a low oxygen tension with an exothermic inert gas generator

Exposure time in days	control	1	2	6	9	14	21
Top samples *	1.1	1.4	3.9	10.0	70.8	97.0	100
Bottom samples *	1.2	1.4	4.2	85.2	96.5	98.4	100

* mean of four replicates.

The exposure time is relatively long compared to research work results of other authors : SHEJBAL *et al* (1973) found that six days exposure time in 1,0 p. cent of oxygen in the atmosphere were necessary to kill *S. granarius* at 22° C. The low temperature in the grain bin during our experiment (10-12° C) and the very low temperature of the generated gas after the gas dessication is disadvantageous for the use of this method. An improvement of the device is in study for the recovery of a part of heat produced by the burner for inert gas reheating before the injection.

The mortality rate obtained with immature granary weevils at all stages of development exposed during the same time than adults was very low (table 2).

table 2 - Rate of transformation in alive adults of immature stages of the granary weevil set inside a 2500 tons wheat bin maintened at a low oxygen content with an exothermic gas generator.

Exposure time in days	control	1	2	6	9	14	21
Top samples *	51	45	48	33	50	56	28 (a)
Bottom samples *	53	60	55	47	61	63	42 (a)

* mean of four replicates (a) = significative decrease of adult emergency rate.

The effects on each immature stage of the granary weevil were estimated on the basis of the development velocity at 25° C, the incubation temperature after the treatment. It was observed that the young adults still inside the grain after imaginal moulting were the most susceptible stage. The other stages are not affected by a fortnight exposure time at a temperature between 10 and 12° C.

Only with the 21 days exposure time, it was observed the first significant lethal effect related to the oxygen depletion.

Similar observations of JAY (1980) and further research work showed that the cold prevention in the immature stages of stored product insects is related to more tolerance of oxygen rarefaction.

It was necessary to generate 3800 cubic meters (m3) of inert gas to lower the oxygen content under 1 p. cent in the grain bin. After the purge, regulated production is about 500 to 750 m^3 of burned gas per day, for keeping up the balance with leakage and gas adsorption on the grain. Over a three weeks exposure, the consumption is about 2600 m3 of propane gas or near a cubic meter of combustible gas per ton of wheat stored. In addition, there was a water supply of 10 m3 per hour for the refrigerating unit during the working time and 10 kVA of electric power.

The short exposure for partial desinfestation realized in practical conditions had a cost of 3,00 FF. or 0,38 $ per ton of treated wheat. The additional cost for a longer storage period is about 0,15 FF or

2.00 cents per ton and per day in our experiment conditions.

At this working fees, we must add up the cost of the material depreciation and of the initial putting of money for plant buying and bin sealing.

CONCLUSION

Results presented here showed that, at a low level of temperature of storage, which takes place in France during winter, the purge of the O_2 content in intergranular space of stored grain by burned air injection could be used over short exposure periods for desinfestation. But, only adults of the granary weevil are susceptible to this treatment during a 21 days exposure at a temperature between 10 and 12° C. Immature stages are not killed in the same time.

The use of exothermic inert gas generators is satisfactory to produce effective control of hidden infestation by weevils only when temperature are above 20° C like in the experiments of STOREY (1973, 1975) or ZAKLADNOI (1976).

A moderate cost similar to the cost of a fumigation with methyl bromide or phosphine is obtained in these conditions. For long term storage periods, the use of absolute air-tight cells is necessary to lower the permanent operational cost which is increased by the natural leaks in all concrete bins.

Aknowledgements. This work was carried out on a storage bin of the harbour silo of the S.I.C.A. - La Rochelle-Pallice (France). Thanks are due to MM BOUCHET and BUISSON, directors, and we are grateful for their help.

REFERENCES

JAY, E.G. & PEARMAN, G.C. Jr (1971). Susceptibility of *Tribolium* (Coleoptera): *Tenebrionidae*) to alterations of atmospheric gas concentrations. *J. stored Prod. Res.*, 7, 181-186.

JAY, E.G. (1980). Low temperatures effects on control of *Sitophilus oryzae* L. with modified atmospheres. *In controlled atmosphere storage of grain.* J. SHEJBAL, Ed. 65-71. Elsevier Amsterdam, 608 p.

LE TORC'H, J.M. (1983). Etude en laboratoire de la sensibilité à l'anhydride carbonique et à l'azote, de plusieurs espèces d'insectes des denrées stockées en vue d'une application à la désinsectisation des stocks. *Agronomie*, 3, (5), 399-406.

NAVARRO, S., GONEN, M. & SCHWARTZ, A. (1979). Large scale trials on the use of controlled atmospheres for the control of stored grain insects. *Proc. 2nd Int. Work Conf. stored Prod. Ent.*, Ibadan, 260-270.

SHEJBAL, J., TONOLO, A. & CARERI, G. (1973). Conservation of wheat in silos under nitrogen. *Ann. Technol. agric.*, 22, 773-785.

STOREY, C.L. (1973). Exothermic inert-atmosphere generators for control of insects in stored wheat. *J. econ. Entomol.*, 66, 511-514.

STOREY, C.L. (1975). Mortality of *Sitophilus oryzae* (L.) and *S. granarius* (L.) in atmospheres produced by an exothermic inert atmosphere generator. *J. stored Prod. Res.*, 11, 217-221.

ZAKLADNOÏ, G.A. (1976). Regulation of the gas composition of the atmosphere for eliminating insects in grain. USSR Ministry of Procurement, Moscow, 3 pp. (in Russian).