PRACTICAL APPROACH TO PURGING GRAIN WITH LOW OXYGEN ATMOSPHERE FOR DISINFESTATION OF LARGE WHEAT BINS AGAINST THE GRANARY WEEVIL, *SITOPHILUS GRANARIUS*

F. Fleurat Lessard and J.M. Le Torc'h

Institut National de la Recherche Agronomique, Laboratoire des Insectes des Denrées, Pont de la Maye, France

Abstract

Exothermic inert gas generators can be used to produce modified atmospheres containing less than 2 % oxygen for disinfesting grain in long-term storage . The effect of this method on infestation of wheat by the granary weevil, was observed on a practical scale during a trial with a 2500-ton capacity vertical bin with an industrial inert gas generator. The treatment consisted of a continuous 15-h purge of the intersticial atmosphere at a flow-rate of 220 m^3/h of inert gas, followed by activation of the burner for only 4 h/day at the same flow rate.

In the samples of infested wheat removed from the bin at various intervals (2, 6, 12, 16, 21, 28, 35, 42 and 47 days) after treatment, complete mortality of free adults of S. granarius was obtained in 3 to 5 weeks, depending on the location of the samples inside the bin. Between 87% and 94% of the hidden infestation had died after an exposure time of 47 days under the same conditions (12.5-15.5°C and 1.5±0.5% O_2).

Total consumption of propane gas during the treatment was 5,850 m^3 and total cost of fuel and tank maintenance was approximately U.S.$ 1430. The operating cost of the plant for the disinfestation was only about U.S.$ 0.60/ton under the above conditions.

Introduction

Exothermic burners are used to produce inert atmospheres from domestic gases like butane, propane or natural gas. The inert atmosphere contains a low level of oxygen (O_2) and can be used to render the grain bins unsuitable for insect survival.

Small scale trials of this method of disinfestation were first carried out in the U.S.A. (Storey, 1975) and in Israël (Navarro et al., 1979). Modification of the generators for compatibility with other ways of gas purification was also recently experimented on in Australia to render the system independant of electric power or water supply on the storage site (Banks, pers. comm.). Storey first observed that the hidden stages of the weevils, Sitophilus spp - the most tolerant grain species to oxygen rarefaction - were killed after four

Proc 4th Int Work. Conf Stored-Product Protection, Tel Aviv, Israel, Sept 1986
[Eds. E Donahaye and S. Navarro], pp 208-217

weeks exposure in a grain bulk at 27°C. Clearly, the relatively high temperature during this treatment produced a high level of respiratory exchange that enabled efficient kill over short exposure times. Reports on trials carried out at lower temperatures are few. It is obvious that similar results could be obtained but with much longer exposure times. However, from the physiological point of view, the inert atmosphere produced by a burner also contains carbon dioxide (CO_2) at a level which is not negligible (table 1). It might be that this small amount of CO_2 in the burned gas would induce a stimulation of the respiratory centers (Le Torc'h, 1983) that would compensate for the decrease in grain temperature.

TABLE 1 - Theoretical composition of the inert atmosphere produced by a propane burner

CO2	11-12 %
CO	0.0
H2	0.0
O2	0.5 %
H2O	saturated at the exhaust temperature
N2	87.5 - 88.5 %

Gas consumption of the exothermic burner
Propane : 10.5 m^3/h = 33.7 liters liquefied propane/h.

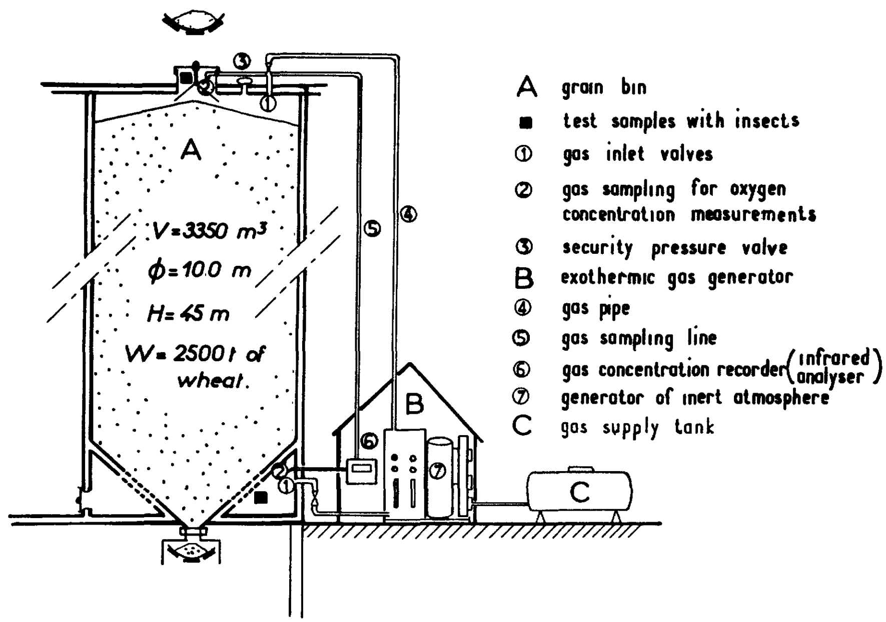
On the other hand, the burners are suitable for high level technologies which exists only in well developed countries for special purposes such as to create inert atmosphere in the head space of fuel tanks, or in tanker ships carrying crude oil, or in the storage of explosive dusts. The use of the burners for grain disinfestation seems to be possible in major grain exporting countries, particularly at terminal elevators, even in temperate climates as in Europe. In the E.E.C. for instance, the grain export trade is generally at a very low level after harvest ; the transactions increase considerably in early winter. During this time, storage facilities are full and it is a convenient period for long term disinfestation with temperatures in a medium range of between 14 and 19°C in the grain.

Our objective was to obtain the disinfestation of a wheat bin in a terminal elevator with a burner in order to determine the feasability of this method of insect control on a commercial scale. In a preliminary experiment carried out during late winter with a grain temperature of only 11 to 12°C, we observed complete kill of S. granarius adults after 3 weeks exposure (Fleurat Lessard & Fuzeau, 1983). In the second experiment presented here, our objective was to kill the hidden forms of the weevil and to evaluate the technical and economical criteria involved in such a technique.

Installation and Methods

The large concrete bins adapted for inert atmosphere treatment were equipped with a perforated base in communication with an air-tight "air-room" surrounding the lower part around the funnel-shaped base. The burned purified gases can enter the "air-chamber" and flow into the grain-bulk through these perforations which surround the upper part of the funnel-shaped base. Inside the bin, these holes are protected by a concrete plate around the wall, close to the funnel junction, to prevent grain from dropping into the "air chamber" (fig. 1). The burned gases can also be injected into the head space over the grain bulk, without a distribution system. The bin was filled with 2500 tons of soft wheat stored at 14.5% moisture content (m.c.).

Fig.1 - Concrete hermetic silo equipped with an exothermic inert gas generator. Diagram of installation with an indication of the position of the insect samples inside a wheat bin of 2500 t capacity.



The generator produced about 200 m3/h of burned gas using 10.5 m^3 of propane (i.e. 33.7 l of liquid propane per h). Cooling of the burned gases was obtained by water washing (18 m3/h) and final drying by a refrigeration unit that lowered the burned gas temperature to 5°C before injection into the bin. The first "purge" took 15 h of continuous flushing of gas through the perforation at the base via the bottom inlet valve, while the security pressure valve remained open. After this "purge" phase the pressure valve was closed and the burned gas was injected only at the top inlet valve. After the "purge", the injection rate of the maintenance phase depends on the level of residual oxygen measured at two points in the bin by an automatic analyser (relayed to activate the burner).

The level of oxygen content was fixed at a threshold of 1.5% though measurements ranged between 1.0 and 2.2% during the treatment. The filling and emptying apertures of the bin were equipped with air-tight covers sealed with rubber joints and counterweights.

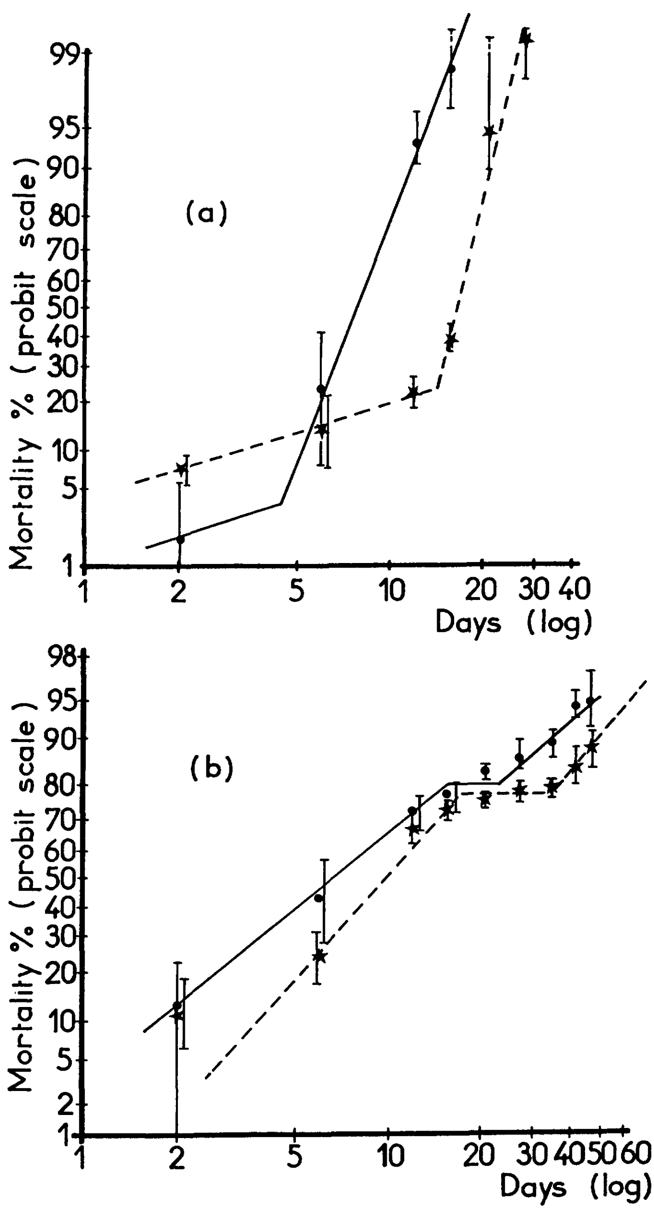
The efficiency of the treatment was observed on infested wheat samples placed at two different points inside the bin (Fig. 1). Control samples of infested wheat were kept in an empty bin or in a rearing room of the laboratory at nearly the same temperature as that in the treated bin. Five samples (replicates) of infested wheat were pulled out at regular time intervals from the two points during a 47 day period. The treated and control samples were sieved to determine free-adult mortality and the remaining grain was incubated at 25°C and 75% relative humidity (r.h.) to evaluate post treatment emergence reduction of adults (I.S.O. project of standard reference method).

Results

1 - Efficacy of disinfestation :

Complete kill of adults of *S. granarius* was obtained in the samples that remained for 21 days at the top of the bin, near the gas inlet valve. At the lower part of bin, mortality reached only 94.5% after the same exposure time and increased to 99.5 % after 28 days under the controlled atmosphere (CA). Five weeks exposure time was necessary to kill all adults of the granary weevil in the samples put in the lower part of the bin (Fig. 2a). The difference between mortality at the two sampling sites can be explained through two observations : a) gas injection and concentration measurements were made at the top of the bin after the first "purge phase" and the level of residual oxygen could be lower at the top than at the lower part, as a result of CO_2 adsorption by the grain during the first part of the treatment, b) grain temperature at the bottom was 1°C lower than grain temperature at the top.

Fig. 2 - Mortality regression lines of the granary weevil in wheat samples placed inside a bin under treatment with controlled atmosphere.
legend : insects at the top of the bin •———•
insects at the bottom of the bin ✶- - - -✶
(a) adults (b) hidden developing stages



The same difference between the two series of infested samples was observed with the hidden stages (Fig. 2b). At the end of the exposure time (i.e. after 47 days under CA) 94 and 81% of the hidden stages were killed in the samples from the upper part and lower part respectively. The pattern of emergence (Fig. 3) shows that the last instar larvae (pre-pupal stage included) and pupae were the most tolerant stages. The young juvenile stages (eggs and three larval instars) were less tolerant. This is in agreement with data obtained on Sitophilus sp. by other authors under laboratory conditions (Storey, 1975 ; Navarro, 1978 ; Jay, 1980).

The regression lines tentatively assessed between emergence reduction rates (probit scale) and exposure time (log scale) have a flat portion in the middle situated between 21 and 35 days exposure (Fig. 2b) in relation to the level of tolerance of the different stages of S. granarius. The curves have two parts : the lower part well correlated with mortality rate of the more susceptible stages and the upper part correlated with mortality rate of the most tolerant stages. Between the two groups of differing susceptibility, the difference is large enough to distinguish a "break" in the increase of mortality.

2 - Technical and economic considerations :

Propane consumption averaged 42.5 m3 per day for nearly 4 h of inert atmosphere production per day. The turn over of the intergranular free space by the inert gas was between 40 and 80% per day after the "purge phase", during the maintenance phase. During the "purge", 2.25 times the free space volume of the silo was injected to obtain the desired threshold of oxygen content. The "purge" phase lasted 15 hours.

The total volume of propane consumed (in liquid form) was 6.922 m3 at a cost of 250$ per m3 under french conditions (Tables 2 and 3).

This represents 40% of the total cost of the disinfestation. Other expenses were as follows : investment for the burner and engineering - 30%, electric power supply - 16%, water supply - 14%. The installation is automatically driven and fees for surveyance were negligible.

TABLE 2 - Technical data recorded during the disinfestation of 2500 tons of wheat with an exothermic inert atmosphere generator during 47 days (test species : Sitophilus granarius).

	burner hours	propane gas consumption (m3) per period	inert atmosphere produced (m3)	ratio of intergranular space turn over	Turn over per day
Maintenance	"Purge" 15.0	157.21	3000	2.25	-
Jo* +2 days	7.5	78.68	1500	1.13	.56
Jo+ 6 d	10.9	114.23	2180	1.64	.41
Jo+12 d	25.3	265.16	5060	3.80	.63
Jo+16 d	21.2	222.18	4240	3.18	.80
Jo+21 d	16.4	171.89	3280	2.46	.49
Jo+28 d	35.9	376.25	7180	5.39	.77
Jo+35 d	29.9	313.36	5980	4.49	.64
Jo+42 d	23.0	241.06	4600	3.45	.49
Jo+47 d	20.3	212.76	4060	3.05	.61
Total 1(including "purge").	205.4	2152.77	41080	30.84	-
Total 2(excluding "purge").	190.4	1995.56	38080	28.60	-
average per day	4.05	42.46	810	-	.661

* Jo = Time of completion of "purge" phase

Fig.3 - Adults emergence from the different hidden stages of <u>Sitophilus granarius</u> after different exposure times to low oxygen atmosphere. Exposure time : control (O) ; 6 days ; - - -21 days ; 35 days ; 47 days.
(relation with the hidden stages living in the grain during the treatment).

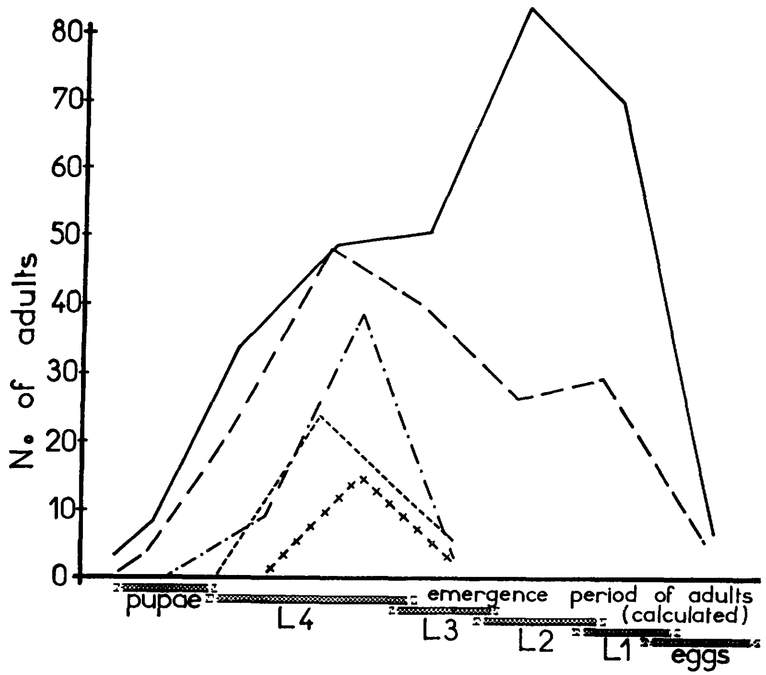


Table 3 - Cost of an inert atmosphere disinfestation of wheat with an exothermic gas burner (duration of treatment : 48 days).

INVESTMENT FOR BURNER AND ENGINEERING IS **133,000$**

(Assuming 5 years of use for treatment of 50,000 tons per year)	$	% TOTAL COST
Cost for disinfestation of 2500 tons	1315	30
Combustible gas used 6922 1 at 250$/m3	1730	40
Electric power 10 kWh	700	16
Water (18m3 per h.)	616	14
TOTAL COST	4361 $	

MEAN COST PER TON OF DISINFESTED WHEAT = **1.7 $**

The average cost per ton of disinfested wheat is relatively high in this type of bin poorly adapted to this treatment namely : 1.7 $ per ton compared with less than 0.1 $ per ton for contact insecticide or 0.8 $ per ton for phosphine fumigation under french conditions. However, after this large scale experimental work we considered that airtightness of the bin was not at all good for low-oxygen atmosphere disinfestation. It is possible, even in temperare climatic conditions to obtain a good level of disinfestation, in a time period of about 6 weeks in airtight bins constructed from materials other than concrete and checked for a good level of airtightness before CA treatment. Under these conditions turn-over of intergranular free-space could be reduced in such a proportion that the cost difference with fumigation would become less evident. Alternatively, the "fumigation" with carbon dioxide might be carried out with 12.000 m3 of gas (in liquid form) under the same conditions and the cost would be reduced to 0.5 $ per ton, similar in price to phosphine fumigation (with the additional fees to undertake the treatment).

Conclusion

Inert atmosphere disinfestation during intervention storage under temperate climates is theoretically a good means of obtaining free-residue insect control in airtight storage structures. However, under the conditions described, in a large concrete bin, a suitable level of airtightness was not reached.

The propane consumption increased the cost in the described pilot experiment and was prohibitive compared with phosphine fumigation or carbon dioxide treatment.

A further finding was that the hidden stages of S. granarius, the test species, were killed only after exposure periods 4 times longer than those necessary to kill the free-living adults.

It has been demonstrated that the transposition of results obtained in the laboratory to a commercial scale must be carried out carefully. The field of interest of burned gas usage for grain disinfestation under temperate climates is dependent on practical factors such as level of airtightness and time available which limits its value when well adapted bins are not available.

Aknowledgement

A part of the technical and financial data was given by the managers of the silo of SICA La Rochelle-Pallice. Thanks are due to MM. BOUCHET and BUISSON who enabled this experimental work to be undertaken.

References

Fleurat Lessard F. and Fuzeau B. (1983) Disinfestation of wheat in an harbour silo bin with an exothermic inert gas generator. In : Proc. 3rd Int. Working Conf. on stored Product Entomol., Manhattan, Kansas, USA. pp 481-485.

Jay E. (1980) Low temperatures : effects on control of Sitophilus oryzae (L.) with modified atmospheres. In : J.Shejbal (Ed.). Controlled atmosphere storage of grains. Elsevier, Amsterdam. The Netherlands, pp 65-75.

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. (1978) The effects of low oxygen tensions on three stored product insect pests. Phytoparasitica 6, 51-58.

Navarro, S., Gonen M. and Schwartz A. (1979) Large scale trials on the use of controlled atmospheres for the control of stored grain insects. In : Proc. 2nd Int. Working Conf. on stored Prod. Entomol., Ibadan, Nigeria, 260-270.

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