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CONTROL OF THE DERMESTID BEETLE *DERMESTES MACULATUS* DE GEER WITH CONTROLLED ATMOSPHERES

ANA C. SÁ-FISCHER, C.S. ADLER AND C. REICHMUTH
Federal Biological Research Centre for Agriculture and Forestry, Institute for Stored-Product Protection, Königin-Luise-Straße 19, D-14195 Berlin, Germany

ABSTRACT

Various hypoxic controlled atmospheres were tested against all stages of *Dermestes maculatus* under laboratory conditions at 25°C and 30°C, both at 75% r.h. Using atmospheres of pure nitrogen (N_2) and pure carbon dioxide (CO_2), respectively, complete control of all stages was achieved within 48 h. The same effect occurred with an atmosphere consisting of 98% N_2 and 2% O_2 by volume. At 30°C with a gas mixture of either 40% CO_2, 44% N_2 and 16% O_2, or 60% CO_2 in air, an exposure time of 96 h controlled all stages. Pupae and larvae were shown to be more tolerant than other stages.

INTRODUCTION

Proper pest management strategies are necessary to minimise economic losses. Problems associated with the use of chemical pesticides, such as worker safety, development of insect resistance and product contamination, draw attention to the development of new strategies and the improvement of existing pest control methods.

The leather or hide beetle *Dermestes maculatus* is one of the most important pests of dried food commodities of animal origin as well as of leather, furs and other materials. Adults and larvae of *D. maculatus* feed on a wide variety of animal products, including dry animal corpses, feathers and fur. In their search for food or a place for pupation, the larvae penetrate into baled tobacco, the woodwork of boxes, fibre-board, vegetable fibre, cork, books, cardboard, linen, cotton, plaster moulds, the lead of fuses and cables, mortar and the stonework of walls (Cline, 1978; Hinton, 1945; Levinson and Levinson, 1978; Nair, 1986). *D. maculatus* damages insect collections and mummies in museums as well as other valuable goods. However, Dermestidae are also appreciated as useful insects in cleaning the skeletons of small to medium sized animals (Hinton, 1945).

Among their natural habitats are bird nests, wasp nests, and sometimes even bee hives. Because they are good flyers, they can also penetrate houses, infesting stored products and materials of animal origin. During dry summers larvae and adult beetles may infest

urban structures in great numbers (Engelbrecht, 1989). Wildey and Wayman (1981) and Binns and Pemberton (1981) reported that three out of every four poultry houses in England and Wales were infested.

In addition to eating chicken feed and other organic matter, the adults and larvae of *D. maculatus* prey on smaller arthropods. They also attack dead or moribund chicks. They have been recorded as injuring, and even killing, young pigeons in pigeon lofts by boring into their wings (Hinton, 1945).

In storage structures and households, *D. maculatus* has been recorded as feeding on bacon, ham, sausages, dry cheese, noodles, dried fish and stuffed animals. *D. maculatus* can cause considerable damage in the processing and storage of dried fish (Taylor and Evans, 1982). In Nigeria 71% of the infestations of dried fish were by *D. maculatus* (Osuji, 1975).

Occasionally *D. maculatus* may have minor deleterious effects on human health, acting as an intermediate host for parasites or as a vector of such pathogenic organisms as nematodes (Hinton, 1945) and enterobacteriaceae (Julseth *et al.*, 1969). Allergic symptoms, including dermal itching, conjunctivitis, irritation of the respiratory tract and nausea, can result from contact with the detached hairs of the larvae.

Laboratory tests have shown that *D. maculatus* is highly tolerant of many insecticides (Pasalu *et al.*, 1974; Taylor and Evans, 1982), and the larvae are less susceptible to a wide range of insecticides than are many other stages of stored-product pests (Lloyd and Dyte, 1965; Ellis, 1964). Insect growth regulators and juvenile hormone analogues have been effective in laboratory tests but their efficacy has not yet been demonstrated in the field (Axtell and Arends, 1990). Such controlled atmospheres as mixtures of carbon dioxide (CO_2) or nitrogen (N_2) with low residual oxygen (O_2) concentrations offer two main advantages for pest control in stored-product protection: the disinfested commodity is residue free and the application is relatively safe. On the other hand, both fairly long exposure periods and gastight enclosures are required. The present study was undertaken to determine the efficacy of various controlled atmospheres at 25°C and 30°C against all stages of *D. maculatus*.

MATERIALS AND METHODS

All test insects originated from cultures at the Institute for Stored-Product Protection in Berlin and were kept in continuously monitored climatized chambers at 25 ± 1°C and 30 ± 1°C, both at 70 ± 5% r.h. The rearing substrate consisted of fish flour and dried pig bones.

In the experiments, four different stages of *D. maculatus* were tested: 24-h-old eggs, 10-d-old larvae, young pupae and young adults.

To obtain eggs, 200 adult beetles were placed on the rearing substrate for 24 h at 25°C and another 200 at 30°C. The eggs were counted and placed in exposure cages, together with some substrate. The substrate served to both maintain relative humidity and prevent friction with the walls of the cage.

Ten-day-old larvae were produced by placing 24-h-old eggs on the food substrate for a period of 10 d after the hatch of the first larvae. Fifty young larvae were counted and placed in the exposure cage with some food substrate.

Two stainless steel wire mesh cages (length 8 cm, diameter 1.5 cm) with 50 insects at each stage were exposed to the experimental conditions, and two other cages with the same population served as control.

Each of the stages was exposed at 25°C and 30°C to the gas mixtures (Table 1).

TABLE 1
Gas mixtures (%) used for the experiments

Mixture no.	CO_2	N_2	O_2
1	100	0	0
2	0	100	0
3	0	98	2
4	40	44	16
5	60	32	8

The experimental exposure apparatus is illustrated in Fig. 1. The procedure of exposure to the gas mixtures was as follows: the exposure cages (y), each containing about 50 individuals of each instar, were introduced into 500 ml Dressel flasks (e) and the flasks were sealed with Vaseline and locked with metal clamps. They were then connected to each other by plastic tubing in the following order: (a) empty safety flask to prevent any backflush of the humidifying mixture from the following bottle; (b) flask with saturated sodium chloride solution to obtain 76 ± 5% r.h.; (c) one or more empty

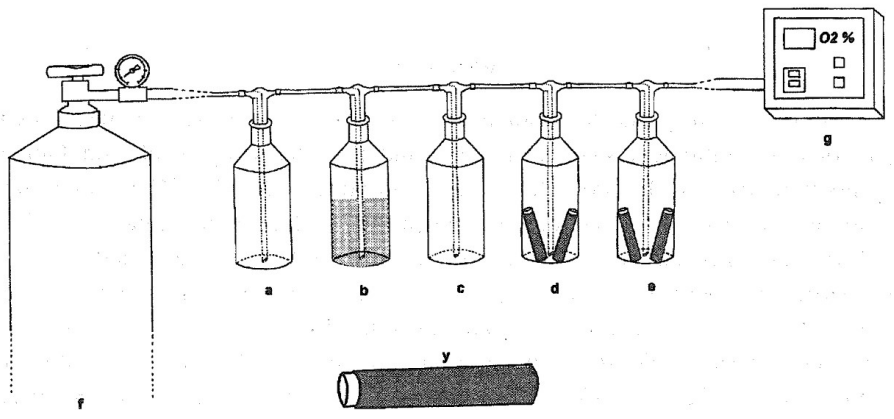

Fig. 1. Set-up of the fumigation experiments: (a) safety bottle; (b) bottle with the saturated sodium chloride solution; (c) empty safety bottle; (d) and (e) bottles with the test insect cages; (f) gas cylinder with the tested mixture; (g) an oxygen analyser; (y) fine metal gauze cage.

safety flasks to prevent accidental overflow of salt solution; (d) and (e) flasks with the test insect cages; and (g) an O_2 analyser. This battery of Dressel flasks was connected to a gas cylinder containing the test mixture (f). The gas was purged through the bottles at a flow rate of 10 ml/h and at a room temperature of 18–23°C for about 1 h. When the required O_2 content had been obtained, the Dressel flasks with the test insect cages were sealed, disconnected and held at the two experimental temperatures. After exposure times of 24 h, 48 h and 96 h, respectively, flasks and cages were opened and the surviving individuals were counted and placed in petri dishes (diameter 10 cm). Mortality rates in each dish were checked weekly for 5 weeks. Each experiment was repeated three times.

The following parameters were checked to determine mortality rates in treated and untreated samples:

1. The eggs, exposed with the substrate, were examined immediately after treatment for colour, size and possible internal development of larvae. Shrunk or darkened eggs were counted as dead but left in the petri dishes for further observation. Dead larvae were removed from the petri dishes. The same procedure was carried out with the untreated controls.

2. The larvae, exposed with the substrate, were examined for mobility and size immediately after exposure. Survivors were counted and left in the petri dishes. Dead larvae were removed. The same procedure was carried out with the untreated controls.

3. The pupae were checked for size, colour and signs of vitality immediately after treatment and subsequently at weekly intervals for 5 weeks. Adults emerging from pupae were counted as survivors, as were pupae that were neither shrunk nor darkened. Eggs and larvae produced after the treatment were not removed.

4. The adults were checked for size and mobility immediately after treatment. During the weekly bioassay surviving and dead adults were counted separately and the dead adults removed. Eggs and larvae produced after the treatment were not removed.

RESULTS

A high rate of mortality due to cannibalism was noted in the experiments. This made comparison of mortality levels between treated and untreated samples difficult. Only in the treatments with 100% CO_2, 100% N_2 and a gas mixture of N_2 plus 2% O_2 were there no survivors of any stage to be found after exposure for 48 h at both temperatures. In these cases, 100% mortality, clearly attributable to the effect of the gas, was noted.

In experiments where larvae and/or adults survived, cannibalism masked the effect of the treatment. This was also true for larvae and adults developing from treated eggs, untreated eggs and pupae during the post-treatment observation process. In untreated controls maximum mortality in 5 weeks was 15% in eggs, 88% in larvae, 65% in pupae and 78% in adults. This high post-mortality rate of both treated and untreated insects will be discussed below.

All egg stages failed to survive exposure to gas mixtures 1, 2, 3 and 5 (Table 1) at 25°C for 24 h. After treatment with mixture 4 the mortality level was less than 100%.

Eggs did not become deformed within 48 h of treatment with any of the gases. Egg mortality, as evidenced by shrinking and colour change, could only be noted within a few days following treatment. Adults survived treatment 4 for the 24 h exposure period.

CO_2 mixtures with 8% and 16% O_2 (treatments 4 and 5) resulted in significantly higher insect survival levels at the higher CO_2 concentration levels than at the lower ones. Larvae were more tolerant than pupae.

Only a few treatments were carried out with gas mixtures 1, 2, 3 and 5 at 25°C and 30°C using an exposure time of 96 h. In all these experiments no insects survived.

DISCUSSION

Usually control of *D. maculatus* is effected by spraying all surfaces with a residual insecticide (Wildey and Wayman, 1981), but this application is problematic in animal houses or museums due to the resulting contamination of walls with persistant poisons.

Neem seed powder has been recommended for protecting dried fish. It controls 93% of the *D. maculatus* larvae within 30 d of exposure (Okorie *et al.*, 1990). However, the disadvantage of neem is its bitter taste, which makes dried fish palatable only after all neem residues are thoroughly washed off.

The use of controlled atmosphere treatments could in theory be successful in controlling *D. maculatus*. In practice, however, there is a problem: a hermetic chamber or enclosure is needed to obtain and maintain the very low O_2 content needed to control the insect in all its stages.

One hundred percent mortality directly after treatment was observed only for 100% CO_2, 100% N_2 and the mixture of N_2 with 2% O_2.

The development of surviving eggs, larvae and pupae was retarded. Treated individuals were often smaller and less active than non-treated ones. Bioassay was difficult to perform due to cannibalism; therefore, smaller numbers of insects per exposure cage, larger post-treatment chambers than those used and ample amounts of food substrate are recommended for this species.

The elytrae and abdomens of some emerging adults were deformed. These deformed adults were more frequently cannibalised than were normally developed ones. Despite the presence of food substrate, most of the dead adults were attacked and devoured but the darkened (dead) pupae were not.

These preliminary experiments indicate that complete control of all stages of *D. maculatus* requires less than 4 d exposure at 25°C and 30°C when the O_2 content is under 2%.

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