Control of the common clothes moth *Tineola bisselliella* (Hummel) (Lepidoptera: Tineidae) and other museum pests with nitrogen

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Abstract

Many products, including wool, fur and bird feathers, are attacked by the common clothes moth, *Tineola bisselliella*. The pest may cause high economic losses in warehouses, museums and households. Thorough prophylaxis and control is of special importance for museum exhibits and other valuable objects. This paper reports on studies of the use of nitrogen as an alternative to traditional chemical means of control of museum textile pests.

Because of their higher susceptibility, the lethal exposure period for moths is presumably shorter than for beetles. From mortality data in stored-product protection it can be presumed that pupae will be most tolerant, followed by eggs. In this study, eggs of *Tineola* were investigated for their susceptibility to high nitrogen and low oxygen atmospheres at 25°C and 32°C. Practical control measures with pure nitrogen have been carried out in collections of cultural institutions and museums. Some results are presented in this paper.

Introduction

The common clothes moth *Tineola bisselliella* (Hummel) (Lepidoptera: Tineidae) and other museum pests are established worldwide and cause damage amounting to millions of dollars (Parker 1990). Especially in museums, due to optimal temperature and moisture for the development of the pests, these losses are severe. Unique artefacts destroyed cannot be replaced. Because of the high economic and cultural value of artefacts and their sensitivity to certain treatments, it is no longer recommended or acceptable to use toxic chemicals, including gases, which tend to react with the artefacts. In Germany and other countries, there are now strong restrictions for the use of ethylene oxide (EO) (Gilberg 1991). Moreover, the health of visitors to museums can be negatively affected by insecticides. Methyl bromide is very effective but it reacts with sensitive surfaces of paintings (Reichmuth et al. 1991). EO reacts with water to form ethylene glycol, which reacts as an aggressive solvent of the exhibits (Florian 1987).

Nitrogen as an inert gas does not react with most other chemical substances. Because of this property it can be used as a replacement gas for life-supporting oxygen, for optimal control of museum pests.

This paper reports on experiments with nitrogen and the eggs of the common clothes moth and summarises some field experiments which have successfully been carried out in German museums to control pest insects.

Material and Methods

Laboratory and field experiments were performed with museum pests, including the common clothes moth as the most important insect. The investigations and the engineering were supported by a team with wide recent experience in the field of stored-product protection (Adler and Reichmuth 1989; Gilberg 1989; Reichmuth 1987; Tunç et al. 1982). These experiences and useful information from the literature could be transferred to the application of nitrogen for museum pest control (Koestler 1992; Gilberg 1989; Pinninger 1992).

Laboratory experiments

The treatments with nitrogen were carried out in 550 mL-Dressel flasks. Several bottles were linked together with tubing. The required gas mixture was prepared by use of manometric instrument (SETARM, Rampé à Gaz) and steel cylinders which were evacuated prior to mixing. For treatment of caged insects in the bottles, the gas was introduced into the system of linked flasks from these cylinders. Between the gas cylinder and the first bottle another Dreschel flask was introduced which contained a saturated $NaNO_2$ solution to humidify the dry nitrogen to 65% r.h. To adjust the flow, a rate metre with a range of 0–20 L/hour was used.

The last bottle in the row was connected with an oxygen analyser (TORAY LF–750), which measured the oxygen content (precision of O_2 determination $\pm$ 0.015 vol.-%).

For breeding, the insect cultures were held at 25°C and 65% r.h. in a constant temperature room. In the course of the laboratory experiments, eggs of different age were tested. To obtain the eggs, adults were placed on felt and removed after 6–12 hours (Titschack 1922, 1926). After ageing at 25°C, the 4 and 5-day-old eggs were placed in special constructed cages with 120 µm mesh screen on one side and fine tissue on the other side. Experimental temperatures were 25°C and 32°C. After the treatment, the hatch rate of the eggs was determined for four days. The higher temperature was expected to lead to higher mortality or faster control (Valentin and Preusser 1990). Every test was accompanied by one untreated control and another control treated only with pressurised air at the same flow rate.

Field experiments

The following treatments were tested.

1. Wrapping the exhibits in PVC-or nylon-laminates and welding together the seams before N_2-treatment. This application can be used anywhere, especially when gastight chambers or rooms are not available and the objects are too brittle to be moved.

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In a museum in Berlin, a nitrogen treatment was carried out in a 30 m^3 commercially available plastic tent. The fumigation process was undertaken as described above. However, the firm involved did not measure oxygen levels and there was no control engineering to adjust for constant low oxygen content.

In a cultural institute in Potsdam, an antique cupboard and other valuable cultural pieces were treated in a bag made of polyethylene. During the two experiments, nitrogen was introduced into the bag up to a pressure difference of 20–50 Pa.

2. Modifying existing fumigation and vacuum chambers constructed for use with toxic gases such as EO, for application of controlled atmospheres, especially in museums.

In the Hamburg Ethnic Museum, two experiments at 20°C and 65% r.h. with nitrogen were performed in a 12 m^3 vacuum chamber. Little modification of fittings and door gaskets was necessary (Reichmuth et al. 1994).

In the course of these trials, control of insects was tested not only in textile exhibits but also in paintings and in test blocks of wood. The chamber was filled as completely as possible to reduce the free space and thereby the N_2 consumption.

The oxygen content in the chamber and the amount of nitrogen needed were recorded (Fig. 1). At the beginning of the fumigation, four cylinders of nitrogen were used to replace most of the oxygen. Another four cylinders were successively used during the experiment. When the pressure difference between the inside and outside of the chamber dropped below 5 Pa, a magnetic switch automatically opened a valve in the connecting tube to the cylinder to keep the nitrogen content within the chamber at a high level.

A second trial in this museum was carried out 5 months later under similar conditions. Together with samples of the common clothes moth, some dermestids and anobiids were distributed equally inside the chamber as test insects.

3. Treatment of cultural or moth-infested objects in systems such as the fumigation 'bubble' from Rentokill[1] or B&G Equipment[1]

4. Fumigation of gastight rooms or whole buildings, such as the herbarium of the Botanical Museum, Berlin.

Results

Laboratory results

These first nitrogen experiments with *Tineola bisselliella* were carried out with eggs of different ages. In comparison to the control group with more than 95% hatch, 100% mortality was achieved after 3 days of exposure to nitrogen at 25°C and 32°C. Oxygen concentration in the test atmosphere was 1.85%.

In a second series of experiments with 2% oxygen in nitrogen at 25°C (Fig. 2), 5-day-old eggs were slightly more susceptible than 4-day-old eggs under the experimental conditions. Complete mortality was achieved after 8 days.

Field experiment results

1. After the treatment of the antique wood cupboard, despite some leaks in the polyethylene foil, all introduced wood pests were found to be dead after 6 weeks of exposure.

2. The aim of the experiments in the chamber was to reduce the oxygen content below 2% during the treatment. Because the gaskets of the door of the chamber were constructed for use under vacuum, the tightness during the overpressure of 5 Pascal (0.000005 bar) was not satisfactory. Due to leakage and ingress of oxygen, the nitrogen content dropped to 96.5%.

During the whole experiment of more than 4 weeks, the average oxygen content could be adjusted to 1.5% which was sufficient to kill most of the introduced pest insects (*Attagenus smirnovi*, *Trogoderma angustum*, and *Anthrenus verbasci*) After the first experiment, only some cigarette beetles, *Lasioderma serricorne*, and one of the hide beetles, *Dermestes maculatus*, survived the treatment.

Some other wood pests exposed (*Anobium punctatum* De Geer, *Hylotrupes bajulus* L. and *Lyctus brunneus* Stephens) did not survive (Reichmuth et al. 1994).

The nitrogen consumption during the first experiment with 8 nitrogen cylinders at 12 m^3, was rather high and affected by undetected leaks. The consumption of the gas is described in Figure 1.

The first 4 bottles were used solely to replace the oxygen, and the last bottle was empty after a short period due to a faulty connection of tubing.

During the experiment, the highest divergence of room temperature from 20°C was ±1°C which resulted from bad climate control of the room containing the chamber. The gas was adjusted to normal room temperature by use of a long copper tube. The relative humidity within the chamber varied widely during the first experiment. Therefore, conditioned silica gel was used during the second trial to stabilise the humidity.

3. The experiment with the commercial tent was cancelled after 8 weeks because of the high oxygen content despite the use of high amounts of nitrogen. All insects survived.

Discussion

Laboratory experiments

The first experiment with slightly less than 2% oxygen was successful within 3 days at both 25 and 32°C.

The lethal exposure time of several days with oxygen contents of 2% lies within the range of results with eggs of stored-product pest moths (Reichmuth 1987). There are not enough data for statistical analysis. On the other hand, the tendency of older eggs to die earlier was confirmed by results at both sublethal exposure periods.

Fields trials

Especially for the treatment in plastics tents, described under 2, gastightness is the crucial condition and must necessarily be installed. Otherwise, the gas consumption will be too high and the treatment too expensive and, moreover, ineffective. An electronic regulating device is helpful and saves time.

The process of filling bags, bubbles, or tents with the exhibits should be as effective as possible, to reduce the empty space.

During the experiments with nitrogen in the vacuum chamber, too much gas was used due to the untight gasket.

The presented trials were performed with commercial 50 L pressurised gas cylinders. In future, other means of supply of nitrogen may be possible, such as pressure swing machines with semipermeable membranes. Krabiell et al. (1992) describe the performance of such a machine producing 150 m^3 N_2/hour. In many cases, nitrogen-application was criticised because of the long exposure times needed. In a museum situation, time is mostly not a restriction.

The length of time needed for effective treatment is also dependent on the thickness of the infested material which has to be penetrated by nitrogen to replace the oxygen. Normally, thick wood needs more time for uniform distribution than textiles.

[1]Quotation of commercial names and trade marks implies no endorsement or recommendation of products.

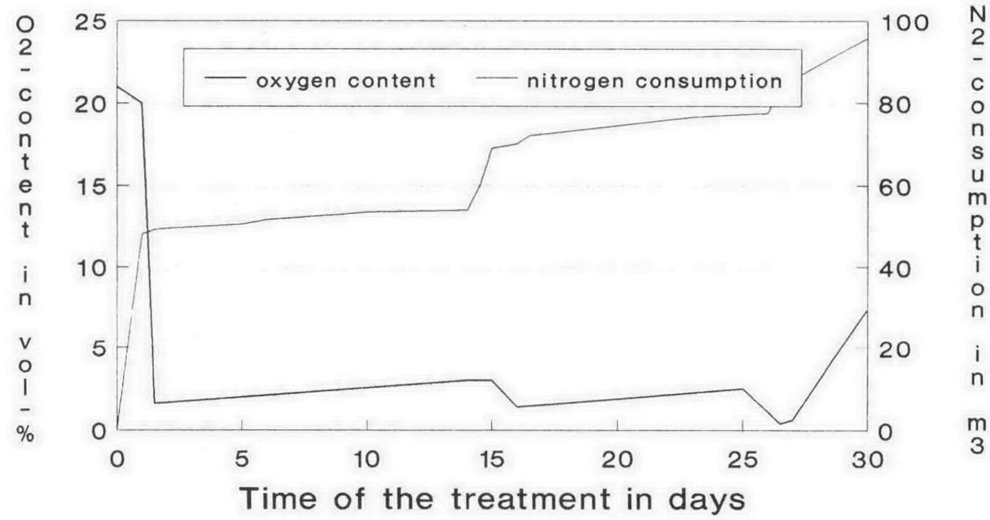

Fig. 1. Nitrogen application in the former vacuum fumigation chamber of the Hamburg Ethnic Museum. The nitrogen consumption and the oxygen content achieved are indicated. Pronounced changes in the slope of the lines correspond to change of the nitrogen cylinders. A total of 93 m^3 of nitrogen was used.

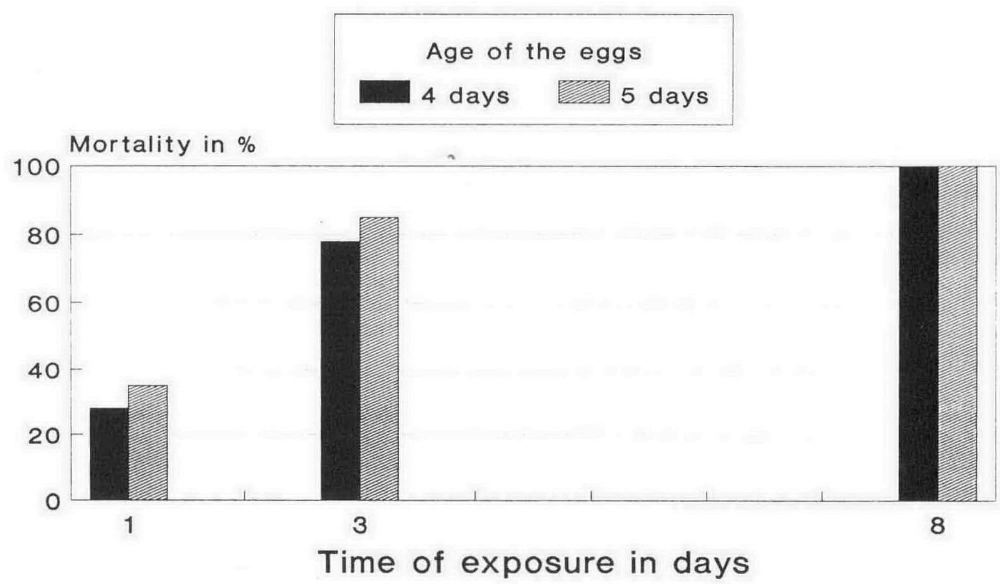

Fig. 2. Mortality of eggs of different age of the common clothes moth after treatment with 2% oxygen in nitrogen at 25°C.

In the field experiment reported, exposure of 4 weeks at 25°C and 65% moisture was sufficient to kill all the pests tested. For the control of wood pests, exposure times of more than 4 weeks are generally necessary (Reichmuth 1993).

For households, it may be convenient, to treat objects such as carpets or artefacts with nitrogen in plastic bags for pest control (Wudtke 1994). Oxygen-consuming substances such as AGELESS® are available to add to the bags to create low oxygen content atmospheres (Gilberg 1990). The cheapest plastic for this purpose is PVC. To evaluate the oxygen-containing air at the beginning of the procedure, only a vacuum cleaner is necessary.

All of the methods of N_2 application presented are practicable and relatively easy to apply, provided sufficient gastightness can be achieved. When calculating the costs of nitrogen treatments and comparing them with use of conventional insecticide treatments, it is necessary to consider not only the economic costs but also the ecological benefits. In the latter context, nitrogen treatment is clearly ahead of treatments with toxic gases.

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