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CONTROLLING RUSTY GRAIN BEETLES WITH CONTROLLED ATMOSPHERES

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ABSTRACT

Mortality of adults, pupae, larvae, and eggs of the rusty grain beetle, *Cryptolestes ferrugineus* (Stephens), was determined at carbon dioxide (CO_2) concentrations of 30, 40, and 60%, at a temperature of 30°C. The oxygen (O_2) concentration was maintained constant at 10% and the relative humidity of gas mixtures was maintained at 75%. The gases were mixed from cylinders of CO_2, O_2, and nitrogen (N_2) at a gage pressure of 35 kPa and the flow rate in an exposure unit was maintained at 55 mL/min. For a 60% CO_2 concentration in the atmosphere, 100% mortality of all the life stages of beetles was obtained in 3 days. For 30 and 40% CO_2 concentration in the atmosphere, all adults were killed within 8 days and all pupae, larvae, and eggs were killed within 4 days.

INTRODUCTION

Controlled atmospheres can be used to control stored-product pests as an alternative to insecticides and fumigants. Pesticides excluding methyl bromide, phosphine, and malathion have been banned for use in stored-products by regulatory agencies in Canada because of their perceived adverse effects on human health and the environment (Bond, 1987). Many stored-product insects have developed resistance to a range of pesticides (Conway, 1987). In controlled atmosphere storage of grains the proportion of the normal atmospheric gases carbon dioxide (CO_2), oxygen (O_2), and nitrogen (N_2), is altered to give a lethal atmosphere to stored-grain pests (Bailey and Banks, 1980).

The mortality of stored-product insects depends mainly on the type and concentration of gases in the mixture, the species and life stage of insects, exposure time, temperature and relative humidity (r.h.), (Bailey and Banks, 1980). Many researchers have conducted experiments to determine the mortality of specific stored-product insects in controlled atmospheres

(Lindgren and Vincent, 1970; Aliniazee, 1971; Navarro and Calderon, 1974; Calderon and Navarro, 1979; Spratt *et al.*, 1985; Soderstrom *et al.*, 1986).

Information on the mortality of rusty grain beetles to controlled atmospheres is needed to make this technique reliable and economical for application in Canada where rusty grain beetles are of great importance. Mortality of adult rusty grain beetles in elevated CO_2 concentrations (>60%) at temperatures common in Canadian grain was reported by White *et al.* (1988). Krishnamurthy *et al.* (1986) studied the mortality of adult rusty grain beetles for low CO_2 concentrations (<30%) and low O_2 concentrations (<2.6%) at 20°C. Rameshbabu *et al.*, (1991) studied the mortality of rusty grain beetle adults and eggs for elevated CO_2 (>60%) and depleted O_2 (<8%) concentrations at 10, 15, and 20°C.

The objective of this study was to determine the mortality of the adults, pupae, larvae, and eggs of the rusty grain beetle in CO_2 concentrations of 30, 40, and 60% at 30°C, 10% O_2, and 75% r.h. The balance of the gas mixture was N_2.

MATERIALS AND METHODS

Experimental Apparatus

A controlled atmosphere unit, developed by Rameshbabu *et al.* (1991), was used in the experiments with a few modifications (Fig. 1). Only one r.h. unit was used to humidify the gas mixture and eight exposure units were used at any one time. A rotameter (Gilmont Instrument Inc.) having a 0-305 mL/min range was used to measure the flow rate of O_2, and two rotameters (Gilmont Instrument Inc.) of 0-2,200 mL/min range were used to measure the flow rates of CO_2 and N_2.

Experimental Design

Mortality of *C. ferrugineus* adults, pupae, larvae, and eggs was determined for CO_2 concentrations of 30, 40, and 60% at 30°C. The O_2 concentration and r.h. were maintained at 10% and 75%, respectively. The gases were released from the cylinders at a gage pressure of 35 kPa and the flow rate in the exposure units was maintained at 55 mL/min. Four replicates were run under each condition. Two replicates were used in the controls.

Experimental Procedure for Adults

Two-month-old adults of *C. ferrugineus* were taken from laboratory cultures on wheat germ and whole wheat (1:19 by weight) at 30°C and 70% r.h. Twenty-five adults and 1 g of wheat germ were placed in each of the four insect boxes of an exposure unit and the controls. Insect boxes were assembled into exposure units and their inlets and outlets were connected to the gas lines from the r.h. unit and exhaust assembly, respectively. Flow meters were adjusted to set the proportion of individual gases (CO_2, O_2, and

N_2) for the gas mixture required in a given experiment. The composition of the gas mixture was analyzed at 12 hr intervals by injecting 5 mL samples into a gas chromatograph with a thermal conductivity detector and a fixed sample-loop volume of 1 mL (Hewlett-Packard model HP9850A, Avondale, PA USA). Relative humidity of the gas mixture was measured at 12 hr intervals using a Vaisala humicap, HM 1698 probe equipped with a thin polymer capacitance sensor and HMI 31 digital meter (Helsinki, Finland).

After each exposure period, one exposure unit was removed and its component insect boxes were dismantled. The flow meters were adjusted to maintain the flow rate at 55 mL/min in the remaining exposure units. The insects from the samples after treatment and those from controls were placed in 1 g fresh wheat germ in glass vials with perforated lids at 30°C and 70% r.h. and the number of live adults was recorded after 168 hr.

Experimental Procedure for Pupae

Gelatine capsules containing 0.5 g ground wheat germ and last instar larvae of *C. ferrugineus* were maintained at 30°C and 70% r.h. until the larvae turned to pupae. Five pupae were put into each insect box of the exposure units and the controls. After every exposure the pupae were transferred to another capsule containing wheat germ and kept at 30°C and 70% r.h. until the emergence of adults. The emergent adults were counted.

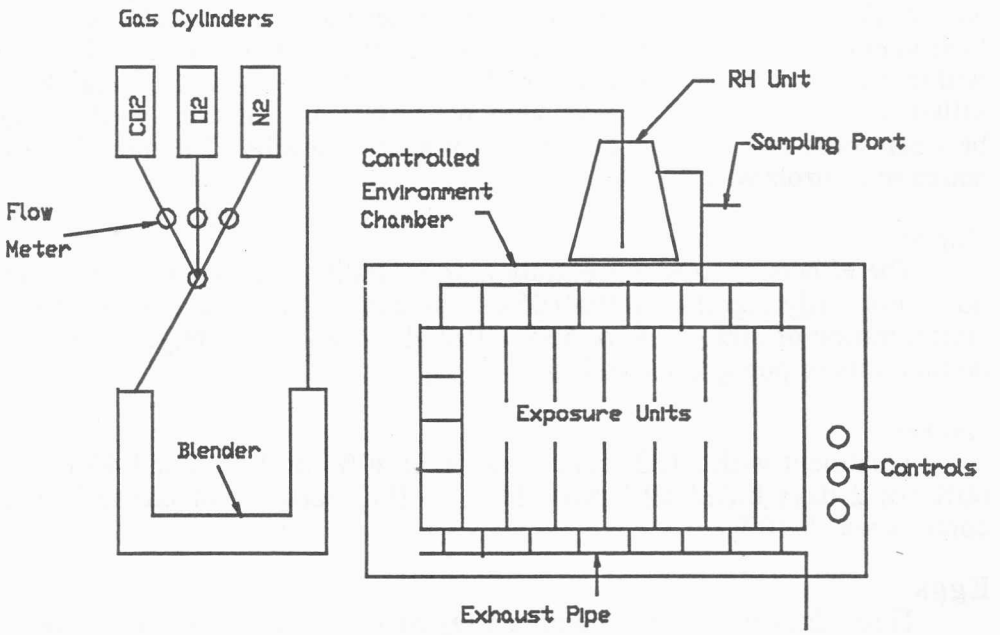

Fig. 1. Schematic diagram of the controlled atmosphere unit.

Experimental Procedure for Larvae

Eggs of *C. ferrugineus* were collected from 250 adults placed on wheat flour and wheat germ maintained at 30°C and 70% r.h. The adults were sifted out and the culture maintained under identical conditions until the development of last instar larvae. Five larvae, each in a gelatine capsule containing 0.5 g wheat germ, were put into each insect box and the controls. After every exposure, the larvae were transferred to another capsule containing fresh wheat germ and kept at 30°C and 70% r.h. until the emergence of adults. The emergent adults were counted.

Experimental Procedure for Eggs

Eggs of *C. ferrugineus* were collected from 250 adults placed on wheat flour maintained at 30°C and 70% r.h. Five eggs, each in a gelatine capsule containing 0.5 g wheat germ, were placed in an insect box and the controls. After every exposure, the eggs were transferred to another capsule containing fresh wheat germ and kept at 30°C and 70% r.h. until the emergence of larvae. The emergent larvae were counted.

RESULTS

Adults

The variations in CO_2 and O_2 concentrations were within ±2% and in relative humidity were within ±3% of the desired values. Mortality of adults was influenced significantly by the exposure period, CO_2 concentration, and their interaction. Treatment with a CO_2 concentration of 60% killed all adults within 3 days (Fig. 2). Treatment with CO_2 concentrations of 30 and 40% killed all adults within 8 days with no significant difference ($P>0.05$) between these two treatments in terms of adult mortality. The mortality of adults in controls was 3-11%.

Pupae

The effects of CO_2 concentration on mortality of pupae (Fig. 3) were not statistically significant ($P>0.05$). Four days of treatment with a CO_2 concentration of 30%, 40%, or 60% killed all pupae completely. There was no mortality of pupae in the controls.

Larvae

Treatment with a CO_2 concentration of 30% for 3 days and 40% and 60% for 2 days killed all larvae (Fig. 4). The mortality of larvae in the controls was 5-10%.

Eggs

Three days of treatment with a CO_2 concentration of 30, 40, or 60% killed all eggs (Fig. 4). The effect of concentration of CO_2 on the mortality of eggs was not statistically significant ($P>0.05$). There was no significant

difference among the treatments of 30%, 40%, and 60% CO_2 in terms of the mortality of all the life stages of the insect on the first day of exposure. The effects of exposure for 3 and 4 days on the mortality of all life stages for all the CO_2 concentrations studied did not differ significantly .

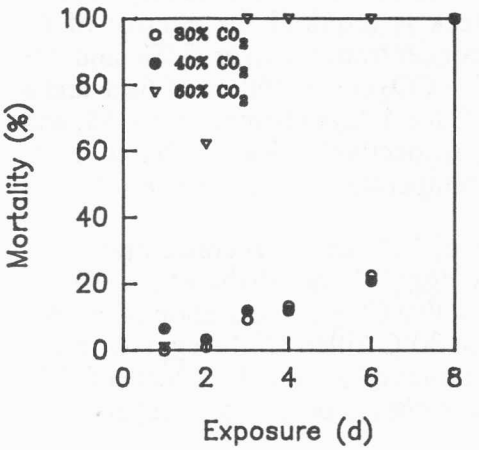

Fig. 2 Mortality of adults exposed to controlled atmospheres (10% O_2; 75% rh; 30° C).

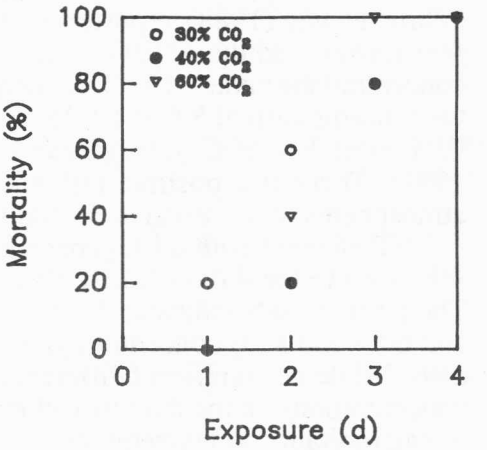

Fig. 3 Mortality of pupae exposed to controlled atmospheres (10% O_2; 75% rh; 30° C).

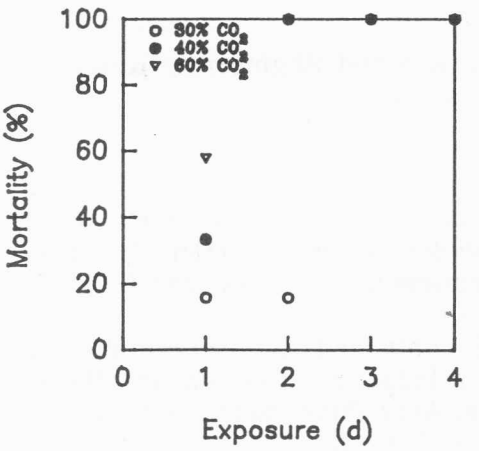

Fig. 4 Mortality of larvae exposed to controlled atmospheres (10% O_2; 75% rh: 30° C).

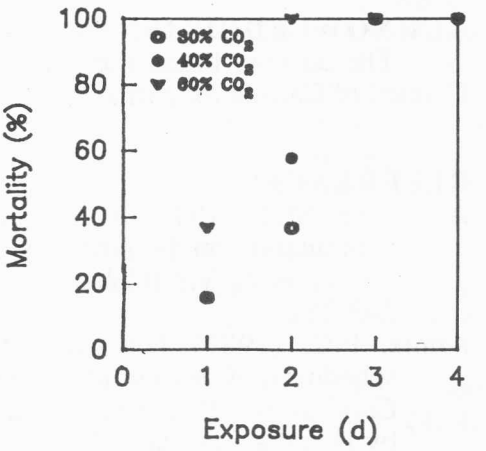

Fig. 5 Mortality of eggs exposed to controlled atmospheres (10% O_2; 75% rh: 30° C).

DISCUSSION

About 3 days are required for control of *C. ferrugineus* at 30°C under an atmosphere containing CO_2:O_2:N_2 (60:10:30%) at 75% r.h. Current moisture content (m.c.) recommendations for CO_2 treatment of grains at or below 14% m.c. and at or above 27°C, excluding those containing *Trogoderma* spp., are a CO_2 concentration of 60% for 5-6 days (Jay, 1984). White *et al.*, (1988) reported that 1 week is required for control of *C. ferrugineus* adults at 20°C with CO_2 concentrations over 54% and O_2 concentrations under 11%. Treatment with a CO_2 concentration of 68% and a O_2 concentration of 8% at 10, 15, and 20°C for 4 days resulted in 54, 58, and 73% mortality of *C. ferrugineus* adults, respectively (Rameshbabu *et al.*, 1991). There is a positive influence of temperature on the action of CO_2 atmospheres on *C. ferrugineus* adults.

Treatment with a CO_2 concentration of 70% and a O_2 concentration of 4% at 20°C for 4 days killed 50% of the eggs (Rameshbabu *et al.*, 1991). The present study indicates that treatment with a CO_2 concentration of 30, 40, and 60% and a O_2 concentration of 10% at 30°C killed all the eggs within 3 days. While no significant difference was observed among the effects of CO_2 concentrations on the mortality of eggs there does appear to be a dependence of egg mortality on temperature.

About 3-4 days are required for control of pupae and larvae, and 8 days for adults with a 30 or 40% CO_2 concentration at 30°C.

At low CO_2 concentrations (40%), adults of *Sitophilus oryzae* and *Trogoderma granarium* are the most susceptible to CO_2 among the life stages studied (Annis, 1987). In our study, we found adults of *Cryptolestes ferrugineus* to be the most tolerant of low CO_2 atmospheres.

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