MORTALITY OF STORED-PRODUCT INSECTS EXPOSED TO EC02FUME'rm FUMIGANT GAS

Thomas W. Phillips*, Ronald T. Noyes, Gerrit W. Cuperus (all of Oklahoma State University), **David K. Mueller** (Fumigation Services and Supply, Inc.), and **Carl Schmidt** (BOC Gases, U.S.)

Methyl bromide is an extremely important tool for fumigation of food processing and warehousing structures, as well as for many other postharvest food uses. Phosphine gas (PH_3) is a possible alternative to methyl bromide and is registered for most postharvest and food uses in the U.S. However, there are several perceived disadvantages to using phosphine for structures. Current formulations of phosphine am pellets or tablets of the metallic salts aluminum phosphide and magnesium phosphide that evolve PH_3 when exposed to air and moisture. Following application of pellets PH_3 increases in concentration over several hours or days, the rate of which is dependent on temperature and relative humidity, until all material is reacted. Gas levels decay as a function of structural leaks and absorption on commodity. Long fumigation times are prohibitive for food plants that can tolerate only minimum loss of production. Precision dosing of PH_3 is difficult due to the dynamic release characteristics of the gas from pellet formulations. High doses of PH_3 combined with high humidity can cause unacceptable corrosion to electrical and electronic circuitry, as well as other metals in a structure.

A new formulation of phosphine, named ECO_2FUME^{TM} Fumigant Gas, is being introduced to the U.S. by BOC Gases, U.S. $EC0_2FUME^{TM}$ Fumigant Gas is a cylinderized formulation of phosphine dissolved in liquid carbon dioxide at approximately 2% PH_3 and 98% $C0_2$. Phosphine gas released from a cylinder of $EC0_2FUNE^{TM}$ Fumigant Gas is not flammable, can rapidly reach a target dose in a structure, is not dependent on air temperature or relative humidity, leaves no dusty residue as with pellet formulations, and can be precisely metered by adding required amounts of gas when needed.

The objective of this research was to evaluate the efficacy of $EC0_2FUME^{TM}$ Fumigant Gas for killing various species and life stages of stored product insects in stored wheat. Additionally, we compared the mortality from ECO_2FUME^{TM} Fumigant Gas with that achieved by a conventional formulation of phosphine pellets, Phostoxin^{TM} from Degesch.
Details of gas dynamics, dosing rates, grain temperatures, and other physical and engineering considerations are given in a companion paper at this conference.

Experiments were conducted in corrugated steel grain bins, 1.8 m dia by 2.7 m high, each containing approximately 4.6 T of hard red winter wheat. Five bins were assigned for treatment with $EC0_2FUME^{TM}$ Fumigant Gas, five bins were assigned for treatment with PhostoxinTm, and one bin was untreated and used for holding control insects for mortality studies. Bins treated with ECO_2FUME^{TM} Fumigant Gas were administered an initial dose of 200 ppm and then re-dosed daily to maintain phosphine gas levels at 160-240 ppm. Bins treated with Phostoxin™ received 34 pellets probed into the center of the grain mass; this treatment represented a minimum dose as recommended by the manufacturer. Phosphine gas levels and temperature were monitored in all bins throughout the course of the seven-day experiment.

Three life stages of each of four species of pest insects were assessed for their mortality in response to fumigants applied to experimental grain bins. Test insects and their life stages included *Rhyzopertha dominica,* the lesser grain borer (eggs, pupae and adults), Sitophilus oryzae, the rice weevil (eggs, pupae and adults), *Tribolium castaneum,* the red flour beetle (eggs, pupae and adults), and *Plodia interpunctella,* the Indianmeal moth (eggs, 5th instar larvae and pupae). Approximately 10 or more of each test species/life stage were placed in small, ventilated vials and deployed in each treatment bin and in the control (unfumigated) bin. Each treatment bin was equipped with a bioassay chamber that was a ventilated PVC pipe, 2 m by 5 cm ID, positioned horizontally across the top of each bin, 15 cm below the top of the grain mass. The bioassay pipe passed through and was sealed to opposite sides of the bin wall. The distal end of the pipe was capped and the proximal end extended past the bin wall to accommodate two PVC ball valves that were 60 cm apart. The space between the valves served as a gas lock through which insect vials connected by string could be pulled from the bioassay tube and recovered with minimal loss of gas from the bin. Vials with untreated control insects were placed in PVC pipe sections and submerged 15 cm below the surface of the grain in the control bin, from which they were removed via the top hatch. Equal sub-samples of treated and control insects were removed from bins daily for seven days and held in the laboratory to evaluate mortality.

One day of exposure to either $EC0_2$FUME™ Fumigant Gas or Phostoxin™ was sufficient to kill all or nearly all adults and pupae of lesser grain borers, rice weevils and red flour beetles, and all larvae and pupae of Indianmeal moth. Eggs of lesser grain borers survived one full day of exposure to test fumigants, but were killed by the second day of treatment. Eggs of red flour beetles were all killed within one day of treatment with either gas formulation. Results with rice weevil eggs were inconclusive due to poor survival of control insects. Eggs of Indianmeal moth survived treatment by both $EC0_2$FUME™ Fumigant Gas and Phostoxin™ at levels ranging from 0.3% to 40.3% relative to control survival. The highest survival of Indianmeal moth eggs was in those exposed for four days, and the highest mortality was recorded from those at the beginning and end of the 7-day trial, which suggests some form of phosphine-induced tolerance was experienced by eggs exposed for four days.

In this experiment each bin treated with $EC0_2$FUME™ Fumigant Gas received a total of approximately 3.6 g of PH_3 while bins treated with Phostoxin™ received about 6.8 g of PH_3 (an amount equivalent to the lowest label rate of 150 pellets/1000 cu. ft.). It is clear therefore that the cylinderized formulation, $EC0_2$FUME™ Fumigant Gas, elicited mortality against stored-product insects comparable to that elicited by the traditional pellet formulation, but utilized nearly half as much active ingredient.