Evaluation of Chlorine Dioxide Gas

While more testing is needed, early results look promising in controlling flour beetles.

Pest Management

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The phaseout of the fumigant methyl bromide (MB) in 2005 in the United States, except for certain critical uses, has created a huge challenge for millers, food processors, and fumigators to find effective and economical fumigant alternatives.

Two important fumigant alternatives to methyl bromide include phosphine as ECO$_2$FUME and sulfuryl fluoride (SF) as ProFume.

Phosphine in the United States is used commonly for fumigating bulk grains, and use by the food industry for whole structure treatment is limited because phosphine is corrosive to metals.

SF is less effective at temperatures below 26.7 degrees C (80 degrees F), especially on eggs of stored-product insects.

Effective kill of eggs requires higher doses or longer exposure times. A nonfumigant MB alternative is the use of heat treatments.

However, heat treatment is not suitable for all facilities, and it is more expensive than MB and may cause adverse effects to structural components of a facility if temperatures exceed 60 degrees C (140 degrees F).

Consequently, there is an urgent need to look for an alternative fumigant source for controlling stored-product insects in food-processing facilities.

Chlorine Dioxide Gas

Chlorine dioxide (ClO_2) gas is a powerful oxidizing agent and is approved for use to control microbiological growth as an antimicrobial in a number of different industries, including food-processing facilities.

The aqueous form of ClO_2 is used as a disinfectant and the gaseous form as a sterilant. The gas has not been evaluated against stored-product insects.

Like MB, any chemical that is effective against microorganisms, as well as ►

insects, would be an ideal replacement for MB and SF.

A preliminary study was designed to evaluate the efficacy of ClO_2 gas against eggs, young larvae, old larvae, and adults of the red flour beetle and confused flour beetle under laboratory conditions in the Department of Grain Science and Industry, Kansas State University (KSU), Manhattan.

Other project collaborators of this study include Dr. Dirk Maier, head, Department of Grain Science and Industry, KSU; Dr. Lakshmikantha Channaiah, research associate, KSU's Grain Toxicology Laboratory; and Chassity Wright, an undergraduate student from Tuskegee University, Tuskegee, AL.

Laboratory Tests

The ClO_2 tablet, which is a mixture of sodium hypochlorite and hydrochloric acid, was donated by Sterling Bridge, Palatine, IL.

Insect life stages of two species – red flour beetle and confused flour beetle – were exposed in a specially designed enclosure (113.3 cubic meters) made of polycarbonate plastic (Secador® Techni-Dome® 360 vacuum cabinet).

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The ClO_2 gas was generated by adding water to the tablet (2 ml per gram of the chemical), and gas concentrations were recorded with a ClO_2-sensor (Optek AF26, Optek-Danulat GmbH, Emscherbruchallee-Essen, Germany).

Eggs (one to two days old), young larvae (first instars), old larvae (sixth to seventh instars), and adults of the red and confused flour beetles from laboratory cultures were used in the tests.

Unsexed adults of mixed ages of each species were collected directly from cultures, whereas other stages were reared to a specific age in 150-ml plastic containers holding 20 grams of the insect's diet.

Fifty insects of each stage were exposed to ClO_2 gas dosages of 380.1, 685.6, 745.0, and 834.4 gh/m^3 (gram hours per cubic meter). The four dosages correspond to 1,500, 2,000, 2,500, and 3,000 parts per million (ppm) per minute. These concentrations x time (Ct) products were achieved in 92 to 120 minutes (1.53 to 2.07 hours).

Insects were exposed to five grams of flour and no flour at all to examine the impact of food on efficacy against insects. All the fumigation experiments were carried out under warm room temperatures, 25 to 30 degrees C (77 to 86 degrees F).

All exposed insects were placed back in 150-ml plastic containers with 50 grams of the flour beetle diet and incubated in a growth chamber at 28 degrees C (82.4 degrees F) and 65% humidity.

Adult mortality was checked 24 hours later and was based on the number of dead adults out of the total exposed.

Immature stages were reared to adulthood, and mortality was based on number of immature that failed to emerge as adults out of the total exposed.

Summary of Results

Table 1 (below) shows the mortality of red and confused flour beetle life stages exposed to ClO_2 in the presence and absence of food.

Mortality of life stages of both species increased with an increase in ClO_2 dosage especially in the absence of food, and commercial kill was observed with young larvae and adults at dosages of 745.0 and 834.4 gh/m^3.

Presence of food decreased activity significantly, which was perhaps due to the binding of ClO_2 gas with the food. Also, adults were more susceptible than the other stages.

Additional laboratory tests with longer exposures and pilot-scale field tests in a food processing facility are needed to determine the viability of ClO_2 fumigant as an insect management tool.

These results demonstrate clearly that the ClO_2 gas at 834.4 gh/m^3 can be used to kill 100% of young larvae and adults of both flour beetles. The eggs and old larvae were the most difficult to kill at the tested dosages.

Exposing life stages to the same dosages over 24 hours rather than 1.53 to 2.07 hours may make the gas more effective.

Other researchers have proven that eggs of stored-product insects are the most difficult to kill using fumigants such as SF and with heat treatments.

Additional laboratory tests with longer exposures and pilot-scale field tests in a food processing facility are needed to determine the viability of ClO_2 fumigant as an insect management tool.

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Table 1. Responses of Life Stages of Red and Confused Flour Beetle Exposed to Four Dosages of Chlorine Dioxide Gas

Species	Stage	Dosage (gh/m^3)	Mean ± SE mortality (%)*	
			Without Flour	With 5g Flour
Red Flour Beetle	Eggs	380.1	1.9 ± 0.9	2.7 ± 0.9
		685.6	2.8 ± .0.9	3.6 ± 0.9
		745.0	4.7 ± 1.6	3.7 ± 0.0
		834.4	9.3 ± 0.9	5.5 ± 0.9
	Young Larvae	380.1	40.1 ± 2.7	6.8 ± 1.8
		685.6	60.1 ± 0.7	9.6 ± 2.4
		745.0	72.5 ± 1.3	13.7 ± 1.2
		834.4	100.0 ± 0.0	18.9 ± 1.2
	Old Larvae	380.1	0.4 ±0.4	0.7 ±0.7
		685.6	6.0 ± 1.8	0.4 ±0.4
		745.0	9.3 ± 1.8	0.0 ±0.0
		834.4	18.8 ± 0.7	4.0 ± 1.2
	Adults	380.1	2.7 ± 0.7	0.0 ± 0.0
		685.6	18.7 ± 2.9	0.0 ± 0.0
		745.0	100.0 ± 0.0	77.3 ± 2.7
		834.4	100.0 ± 0.0	100.0 ± 0.0
Confused Flour Beetle	Eggs	380.1	4.6 ± 0.9	1.9 ± 0.9
		685.6	7.4 ± 0.9	1.9 ± .09
		745.0	9.3 ± 2.4	1.9 ± 0.9
		834.4	11.1 ± 1.6	5.6 ± 1.6
	Young Larvae	380.1	43.5 ± 2.7	16.3 ± 2.4
		685.6	87.1 ± 1.4	29.5 ± 1.4
		745.0	90.0 ± 0.0	38.8 ± 1.2
		834.4	100.0 ± 0.0	37.2 ± 2.3
	Old Larvae	380.1	0.7 ± 0.7	0.0 ±0.0
		685.6	12.7 ± 1.3	0.9 ± 0.4
		745.0	26.8 ± 0.7	6.7 ± 1.3
		834.4	31.3 ± 0.7	14.7 ± 1.3
	Adults	380.1	4.0 ± 1.2	0.0 ± 0.0
		685.6	29.3 ± 0.7	2.0 ± 1.2
		745.0	100.0 ± 0.0	100.0 ± 0.0
		834.4	100.0 ± 0.0	100.0 ± 0.0

* Each mean is based on three replications.