FEATURE

Methyl bromide debate continues

by Dr. Bhadriraju Subramanyam

Many flour mills are still using the controversial fumigant under the critical use exemption, but a number of case studies indicate several alternative pest control products are also effective

Because of year-round warm temperatures and the constant availability of food, flour mills are ideal habitats for supporting infestation by insects.

Suggested pest management methods for flour mills involve stock rotation, sanitation, aspiration, use of impact machines, crack and crevice treatment with inert dusts or residual products and exclusionary tactics such as closing doors, using air curtains near entrances and screening windows. Space treatments include the use of the fumigant methyl bromide and fogging with several approved insecticides.

Methyl bromide is a broad spectrum fumigant used for killing insects, mites, rodents, microflora and nematodes. About 75% of the methyl bromide that is available commercially is used as a soil sterilant, while 13% is used for treating durable commodities, 8% for treating perishable commodities and about 3% for treating structures (food processing facilities, warehouses, etc.).

In 1974, a paper by M. J. Molina and F. S. Rowland published in *Nature* indicated that chlorinated fluorocarbons used as refrigerants and aerosol propellants might be causing damage to the stratospheric ozone, found 19 to 23 kilometers above the earth.

This layer is responsible for absorbing ultraviolet-B radiation from the sun. A loss or thinning of the ozone layer allows ultraviolet-B radiation to reach the earth, resulting in increased skin cancers and cataracts in humans as well as causing adverse effects in animals and crops.

In 1985, the appearance of an ozone hole over the Antarctic led to the establishment of the Montreal Protocol on Substances that Deplete the Ozone Layer. The group, which now includes most countries, works to protect the stratospheric ozone from further depletion.

In 1992, through the Copenhagen Amendment to the Montreal Protocol,

HLT and dosage: pet food facility
(Target pest: Indianmeal moth)

Area	Estimated HLT (h)	Observed HLT (h)	% of Fumiguide target Ct	Observed, % of target Ct
Grinding room and office	5	14.5	100%	145%
Bag house	5	17.4	100%	159%
Production room	5	16	100%	158%
North warehouse	6	14.3	100%	184%
East warehouse	7	16.2	100%	189%
Average for structure	5.6	15.7	100%	166%

HLT — half-loss time Ct — concentration time methyl bromide was added as one of the substances responsible for ozone depletion. All parties to the Montreal Protocol and subsequent amendments agreed to establish timelines to phase out methyl bromide production and consumption using the 1991 figures as the baseline, while making allowances for using methyl bromide for certain critical uses.

The critical-uses category includes food processing facilities or commodities where alternatives to methyl bromide are unavailable, not cost-effective or pose an adverse effect to sensitive equipment in a facility. The provision for critical uses also gives users of methyl bromide adequate time to transition to an alternative, if one is available.

Although flour mills use relatively small amounts of methyl bromide, it is one of the important tools available for insect management, especially in facilities that operate 24 hours a day, 7 days a week.

The push to phase out methyl bromide has renewed interest in exploring alternative fumigants and methods for insect management in mills worldwide. The alternatives include a formulation containing 98% carbon dioxide and 2% phosphine (ECO$_2$FUME) that can be used in combination with heat and carbon dioxide and sulfuryl fluoride (ProFume). Both of these fumigants were recently approved for space treatment in mills.

The use of heat treatments, a pest control method that has been around for some time, is also becoming popular as a methyl bromide alternative.

Phosphine by itself is not an ideal fumigant for use in structures because of the high concentrations (900 ppm) and length of treatments (more than 36 hours is required). At this concentration, phosphine is highly corrosive to copper, but it can be successfully used at 80 to 100 ppm in combination with temperatures of 30 to 36 degrees C (86 to 97 degrees F) and carbon dioxide levels of 3% to 7%.

Many practical and successful fumigations have been conducted using phosphine with heat and carbon dioxide.

In this article I will present information on ProFume and heat treatments as viable alternatives to methyl bromide because of my personal research experiences with these technologies.

PROFUME

Research by Dow AgroSciences in the early 1950s identified sulfuryl fluoride as an alternative to methyl bromide for structural treatment, and in 1961 Vikane gas fumigant was marketed for treating structures to control dry wood termites.

In 1995, Dow started examining sulfuryl fluoride as a methyl bromide alternative for the management of post-harvest insect pests, especially in food processing facilities. ProFume was approved by the U.S. Environmental Protection Agency (EPA) for structural treatment of food processing facilities in January 2004 and for pet food facilities in July 2005.

ProFume was also registered by the EPA in 2005 for dried fruit, pistachios, walnuts, dates and beans. It is also approved

For more information, see Page 94.

for use on processed foods, spices and herbs, cocoa, cheese processing facilities and ham (for red-legged ham beetle control). Besides the U.S., ProFume is registered in Belgium, Canada, France, Germany, Italy, Switzerland and the U.K.

ProFume comes in 56.75-kg (125-pound) cylinders that contain 99.8% sulfuryl fluoride. For fumigation of facilities, ProFume is used emphasizing Precision Fumigation principles. Precision Fumigation can be defined as optimizing fumigant use to maximize efficiency and minimize risk. Under this concept, four interrelated fumigation factors such as pests and stage of pests to be controlled, temperature, half-loss time (gas confinement) and exposure period are taken into consideration in customizing a fumigation plan and execution.

Proper fumigant introduction, circulation, aeration and worker safety are also emphasized under this concept. The ProFume Fumiguide, a software program, is used to determine the correct dosage (concentration of gas and exposure time) needed, and this program takes into account all of the Precision Fumigation principles. The program also records all fumigation data and generates graphs and reports for the users.

By implementing Precision Fumigation, an enhanced level of professionalism is being accomplished and the Precision Fumigation approach should be a standard practice for any new fumigant being developed.

PET FOOD FACILITY CASE STUDY

An 18,720-cubic-meter pet food facility was fumigated in June 2003. The average temperature of the facility was 28.9 degrees C (84 degrees F) and the humidity was 47%. The total fumigation time was 17 hours, 30 minutes followed by an aeration time of 3 hours, 45 minutes.

The fumigation was done to control an Indianmeal moth infestation. The gas was introduced from the outside at eight points within the facility. Gas concentrations were monitored at eight points close to the areas where the gas was introduced. The table on page 52 shows the estimated and observed half-loss time (HLT) in hours and the predicted gas dosage and actual (observed) gas dosage.

When using ProFume for the first time, the HLT value has to be estimated using the best judgment of the fumigator based on expert opinion. This value can be easily revised after the first ProFume fumigation.

In the example, 66% more than the target concentration time (Ct) was used in the pet food facility, resulting in using 19 cylinders of gas instead of 8.

As evident from the table, the facility was more gas-tight than originally determined (5 to 7 hours), resulting in a HLT that ranged from 14.3 to 17.4 hours.

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Because the facility was thought to be "leaky" or "less gas-tight," more ProFume was introduced into the facility.

Although Indianmeal moth was the target pest, bioassays were conducted with six additional species and the results are shown in the table above. In these bioassays, eggs, larvae and adults were used and 100% of all stages were killed, except for the red flour beetle, in which 96% of the eggs were killed.

Bioassays with insects: pet food facility
(Target pest: Indianmeal moth)

Species	Stage	Number of samples	Mean ± SE mortality (%)
Indianmeal moth	Eggs	6	100
	Larvae	6	100
Confused flour beetle	Larvae	7	100
Sawtoothed grain beetle	Eggs	6	100
	Adults	6	100
Warehouse beetle	Eggs	6	100
	Adults	10	100
Larger black flour beetle	Adults	3	100
Yellow mealworm	Larvae	4	100
Red flour beetle	Eggs	6	96 ± 2.1
	Adults	6	100

FLOUR MILL CASE STUDY

A flour milling facility was fumigated in May 2003 for the second time, and the HLT values from the first fumigation were helpful in optimizing the amount of ProFume gas needed for the second fumigation. The facility was 13,938 cubic meters and the temperature and humidity were 25.6 degrees C (78 degrees F) and 46%, respectively. The total fumigation time was 20 hours, 30 minutes followed by a three-hour aeration time.

Bioassays during fumigation were conducted with three species: the red flour beetle, Indianmeal moth and warehouse beetle (see table, page 57). Insects were confined in bioassay boxes, and there were six samples for each species placed in different areas of the mill. All adults of the red flour beetle and Indianmeal moth and larvae of the warehouse were killed. Mortality of the eggs of the Indianmeal moth was 98.3% (plus or minus 1.7%) and the egg mortality of the warehouse beetle was 95.3% (plus or minus 2.6%).

PROFUME COMMERCIAL FUMIGATIONS

A wealth of information on ProFume is available from the fumigation of commercial wheat mills, rice mills, food processing facilities, feed mills, bins, chambers and tanks throughout the world. The data generated not only shows the dosages of ProFume used but also the duration of effectiveness as determined from sampling insects before and after fumigations.

In the U.S. alone, 130 commercial fumigation jobs were conducted from 2004 to 2006. A total of 53 wheat mills and warehouses and 30 rice mills and warehouses were fumigated during this two-year period. In the 53 wheat mills, the average total fumigation time was 23.6 hours, the average HLT was 12.7 hours and the average Ct was 565. The mean initial dose (pounds per cubic foot) was 2.4 and the mean final dose was 3.

In the 130 fumigations representing 84 sites, the mean Ct ranged from 565 to 857, the mean initial dose ranged from 1 to 2.5 and the mean final dose ranged from 1.1 to 3. These tests were conducted under a range of environmental conditions in various geographic locations.

Customer and fumigator surveys indicated that they were satisfied with ProFume.

Laboratory research conducted by the Dried Fruit Association of California showed that ProFume is less effective on eggs of the warehouse beetle. At 487 Ct, the mortality was 52.9%, while at 998.4 Ct it was 100% at 26.7 degrees C (80 degrees F) after 24 hours of exposure.

Corresponding mortalities at the two Ct's for the red flour beetle eggs were 54.4% and 95.9%, respectively. All Indianmeal moth eggs were killed at the lower Ct. With methyl bromide, a Ct of 169.2 killed 100% of the eggs of all three species.

Even though ProFume does not kill all the eggs, there is very little evidence to show that population rebounds following fumigation are related to egg survival. For instance, population rebound studies show that the capture of insects in traps in mills receiving either methyl bromide or ProFume is the same.

Eggs of stored-product insects are laid in product accumulations in mills. Therefore, a good sanitation program in the facility should remove eggs in product accumulations both within and outside the equipment. Tests done in the U.S. and U.K. strongly suggest that population rebounds are primarily due to lack of inspection of inbound product and lack of proper pest exclusion practices.

A commercial fumigation company that made a commitment to switch to ProFume from methyl bromide has performed over 100 fumigations. According to the fumigator, the increased cost with ProFume when "add gas" is needed was less than U.S.$500 when compared with that of methyl bromide. On the other hand, a single fumigation with ProFume in several instances eliminated the need for additional intervention with spot treatments (fogging) or another fumigation, resulting in cost savings of nearly U.S.$24,000.

HEAT TREATMENTS

Slowly raising the ambient temperature of the milling facility or a portion of it to 50 to 60 degrees C (122 to 140 degrees F) and holding these temperatures for 24 to 36 hours is an effective and time-tested technology.

Before conducting a heat treatment, it is important to determine if it is the correct choice for disinfesting your facility. Planning for heat treatment should begin several months prior to the actual treatment. It is important to first do a thorough job of sanitation of the entire facility or the area being treated.

All heat-susceptible products and any food products that provide insulation from heat to insects should be moved out of the facility, fumigated and then returned to the mill after the heat treatment to prevent reinfestation.

It is important to determine the amount of heat required (British Thermal Units (BTU) per hour for the entire 24 to 36 hours) for the treatment. These values are based on a set of heat-loss calculations. Heat-loss calculations measure amount of heat lost due to exposed surfaces (floors, walls, junctions, windows, doors, etc.), steel (equipment) and infiltration (leaks).

Bioassays with insects: flour milling facility

Species	Stage	Number of samples	Mean ± SE mortality (%)
Red flour beetle	Adults	6	100
Indianmeal moth	Eggs	6	98.3 ± 1.7
	Larvae	6	100
Warehouse beetle	Eggs	6	95.3 ± 2.6
	Adults	6	100

Irrespective of the facility or area being treated, it is important to provide at least 7 to 10 BTU per hour per cubic foot of the area being heated, based on our research using the Heat Treatment Calculator developed at Kansas State University. If the target temperature of 50 degrees C (122 degrees F) takes more than eight hours from any ambient temperature, then it is safe to assume that enough BTU are not being introduced into the facility.

Whether a heat treatment is effective or not will depend on how well heat is distributed by air movers or fans. Placement of fans to accomplish uniform heating and determining the

For more information, see Page 94.

HLT and dosage: flour milling facility
(Targeting: post-embryonic stages)

Mill area	First fumigation HLT (h)	Second fumigation HLT (h)	% of Fumiguide target Ct	Observed, % of target Ct
Basement	8 hrs	7.5 hrs	100%	87%
1st floor (Mill + warehouse)	7 hrs	6.9 hrs	100%	90%
2nd floor (Mill + warehouse)	7 hrs	7.2 hrs	100%	100%
3rd floor	7 hrs	6.6 hrs	100%	104%
4th floor	7 hrs	6.1 hrs	100%	112%
5th floor	5 hrs	5.9 hrs	100%	112%
Average for structure	6.8 hrs	6.7 hrs	100%	101%

HLT — half-loss time Ct — concentration time

number of fans needed is more of an art than science. Therefore, monitoring temperatures during heat treatment is critical to prevent development of "hot spots" and "cool spots."

How heat behaves within a facility cannot be predicted, so before conducting a full-fledged heat treatment it is important to try it on a small scale. Every heat treatment is a learning experience. There will always be cool spots or extremely hot spots present in any heated facility, because every room within a facility heats at a different rate. Sanitation, application of diatomaceous earth or any residual product will help in controlling any surviving and mobile insects, especially in cool spots.

Evaluation of insect numbers before and after heat treatment showed that, like fumigation, insect populations rebound within one to two months because of poor sanitation and exclusion practices.

A Canadian study reported that the cost of heat treatment was more than three times that of a methyl bromide fumigation. For heat to become cost-competitive with methyl bromide or sulfuryl fluoride, it is important to develop ways to optimize heat treatments. The use of KSU's Heat Treatment Calculator and a new model KSU developed for predicting survival of the heat-tolerant stages of red flour beetle (young larvae that hatch from eggs) and confused flour beetle (old larvae close to becoming pupae) during heat treatment should enable this treatment method to be corrected and completed in less than 24 hours.

A recent test at a commercial facility showed that heat treatments can be successfully completed within 18 hours. Heat treatment service providers and users of heat treatment need to put a greater emphasis on ways to optimize heat treatments, thereby making them as cost-competitive as fumigants so the milling industry can embrace another viable tool for insect management.

The book "Insect Management for Food Storage and Processing" contains a chapter that provides a step-by-step procedure for conducting a heat treatment. Also, more information about heat treatment technology can be obtained from the following website: www.oznet.ksu.edu/grsc_subi. WG

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