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FUMIGATION PRACTICES IN FOOD PROCESSING PLANTS: STRIVING FOR "BEST PRACTICES" THROUGH IMPROVED EFFICIENCIES WITH SULFURYL FLUORIDE

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ABSTRACT

The food processing industry faces new challenges as a long-time pest management commodity fumigant favorite, methyl bromide (MB), is phased out. Many of the wide variety of MB uses have already been replaced with alternative pest management strategies, while many others continue unchanged. Among alternative strategies to MB are a limited number of other fumigants, one being sulfuryl fluoride, developed by Dow AgroSciences. Ongoing field trials are conducted to improve the efficiency of fumigation through improvements in gas introduction and structure sealing techniques. Four years of research fumigations of empty food processing plants, have shown that relatively simple enhancements in gas introduction procedures and structure sealing techniques can result in considerable improvements in shortening gas introduction times and lengthening gas retention times. This results in an increase in fumigant efficiency through equal to better insect pest efficacy using less fumigant. In case studies of monitored sulfuryl fluoride fumigations of empty food processing plants, with efforts to achieve "Best Fumigation Practices", results have demonstrated the following improvements in gas efficiency: (a) >50% reduction in gas introduction times; (b) 1.5- to 8-fold increase in gas retention; (c) >70% decrease in variation of gas retention across structures; (d) nearly 80% decrease in variation of gas concentrations across structures, and; (e) accumulation of 44-66% greater Ct dosages with 27-36% less fumigant. These kinds of fumigation improvements are critical to the continued viability of fumigation as a tool in stored-product pest management programs of the future.

INTRODUCTION

The food processing industry faces new challenges as uses of a long-time pest management commodity fumigant favorite, methyl bromide (MB), are phased out. Among alternative strategies to MB are a limited number of other fumigants, one being sulfuryl fluoride (SF). Dow AgroSciences LLC developed SF as a structural fumigant nearly 40 years ago and has been marketing it since as a termite and wood-infesting beetle fumigant, under the trademark of Vikane* gas fumigant. Over the past several years, Dow AgroSciences has been developing a data base to support new uses of SF as an alternative to MB as a food processing plant (FPP) and food commodity fumigant that will be marketed as ProFume* gas fumigant.

MATERIALS AND METHODS

Several SF research fumigations of empty (no food/feed present) FPP structures were conducted by Dow AgroSciences in cooperation with food processors, commercial fumigators and government agencies in the U.S. and Europe. The objectives of these trials were: to validate lab-generated dosages for key stored-product insect pest (SPIP) species; to determine gas retention characteristics (measured as Half-Loss Time, or HLT) of fumigated FPP structures; and to evaluate various enhancements to standard gas introduction and structure sealing techniques and to identify "Best Fumigation Practices" that optimize efficient use of SF, as well as other fumigants.

Achievement of "Best Fumigation Practices" is a dynamic process in which continuous efforts are made to obtain equal or better SPIP control with less fumigant.

A total of 18 SF fumigations, involving 13 FPP locations (including 4 fumigation chambers) were conducted by Dow AgroSciences from 1977 though 2000. Where possible, the same FPP structure was fumigated multiple times in order to better document the impact of various enhancements to sealing and gas introduction and distribution techniques. Structure size ranged in volume from ca. 2,237 m^3 to 23,000 m^3. Fumigation efficiencies were evaluated by monitoring the fumigant throughout the structures and comparing concentrations over time, across floors, and for structures sealed through varying techniques. The expectation was that the monitoring data would provide guidance on enhanced sealing and gas distribution techniques to shorten the time to equilibrium, optimize gas retention within the structure, and maintain gas equilibrium during exposure. A variety of gas introduction techniques were evaluated, by recording the time to introduce the specified amount of fumigant, and measuring the gas concentration across introduction sites.

RESULTS AND DISCUSSION

Gas introduction process

The goal of any fumigant introduction process should be to introduce the fumigant as quickly and efficiently as possible while not damaging any materials within the fumigated structure. For fumigants released from cylinders, the total amount of fumigant to be introduced and the delivery rate (kg/min) are factors to be considered in determining the number of shooting lines necessary to introduce the fumigant within the desired introduction time. Delivery rate for both MB and SF is influenced by temperature and managed by shooting line size (length & inside diameter), and shooting fan air movement capacity (m^3/min). Due to the physical characteristics of SF, a maximum delivery rate should not be exceeded under conditions of a narrow dew point deficit, to avoid condensation or "fog-out" conditions. However, rapid delivery from the gas cylinder can still be achieved by distributing the released gas into a manifold with multiple shooting outlets with slower delivery rates, and the proper use of fans to disperse the SF.

Simple calculations can me made to determine numbers and sizes of shooting lines (and manifolds, if necessary) and fans to allow release of the fumigant from the cylinders and efficient distribution within the desired shooting interval. The quicker the fumigant is introduced and equilibrated, the quicker the desired dosage begins to accumulate, and the more efficient becomes the fumigant.

With an equivalent volume and target dosage, doubling the cylinder release rate reduces the total introduction time by half. With sufficient numbers of shooting and circulation fans, fumigant equilibrium can be achieved shortly after introduction is complete, and accumulation of the desired dosage is optimized. Even in a large 6-floor structure in which the delivery rate was limited to avoid a fog-out, gas equilibrium across all floors was achieved shortly after the completion of gas introduction. The fumigant was released through six separate shooting line sets. Each set consisted of a large-diameter (0.64 cm i.d), rapid-delivery rate shooting line from the cylinder to a single manifold on a particular floor. At the manifold, gas was distributed into three or four smaller-diameter (0.32 cm i.d.), slower-delivery rate shooting lines, and each line was attached to a shooting fan with an air movement capacity of at least 6.3 m^3/min per kg of fumigant released from of the shooting line.

Gas retention

The goal for any fumigant in optimizing gas retention should be to increase the HLT for particular areas of the structure, and the structure as a whole, to provide a more efficient accumulation of the desired dosage. SF dosages are determined as a function of concentration (C) and exposure time (t), and are referred to as "Ct" and measured in $g \cdot h/m^3$. By increasing the HLT, more gas is retained within the structure over time to contribute to the desired accumulated Ct. Increasing HLT values provides the benefit of accumulating dosages in a shorter time period or with a lower concentration. The commercial benefit can be either shorter plant shutdown times or lower fumigant costs.

HLT values can be increased with improvements in sealing efforts. Enhanced sealing techniques evaluated in our trials were: Combinations of multiple-layer *vs.* single-layer tape, sprayable foam to fill small openings and holes in walls plus sealing around unused doors and supplementing polyethylene stuffing and tape in equipment augers, and tarping rather than tape-sealing the structure.

HLT values of the FPP structures we tested ranged from about 5.5 to 18.3 hours (median ca. 10 h), with some areas within certain structures having HLT values of less than 2 hours. By comparison, the fumigation chambers tested had HLT values of 48 hours to no detectable loss during 15-h exposures. Tarp sealing improved HLT values over standard tape-sealing at one structure by over 7-fold (from 8.8 to 64.6 h). Enhanced tape and foam-sealing efforts improved HLT values at another structure by about 1.6-fold (from 8.4 to 13.3 h). Considerable opportunity exists to improve gas retention in FPP structures with either more thoughtful use of available standard sealing techniques or application of new and novel sealing concepts.

Maintaining gas concentration equilibrium

Once fumigant equilibrium is achieved, the goal should be to maintain that equilibrium throughout the structure for the duration of the exposure interval in order to maximize the dosage in all parts of the structure. This can be accomplished with a combination of improving gas retention across the structure and using circulation fans. In some instances, where air circulation between areas is limited, such as between some floors, fans with convection ducts can direct the air as needed from high to low concentration areas.

In these trial fumigations, variations in HLT between different areas of the structure without enhanced sealing efforts ranged from about ± 4% to ± 56% of the mean HLT. High variability in HLTs across the structure indicates either gas-inefficient dosing in selected areas in order to achieve desired dosages in the leakiest areas or the acceptance of poor insect kill in these areas.

By maintaining fumigant equilibrium across the structure, fumigant use is optimized, thereby achieving the desired level of control throughout the structure with the least amount of fumigant. In one trial, the variation in HLT across the structure without specific efforts to maintain the equilibrium was ± 23.6%, and the associated variation in Ct was ± 26.6%. In a follow-up trial, employing specific efforts to maintain the equilibrium in this structure resulted in an 87% reduction in variation of HLT across the structure (from ± 23.6% to ± 3.0%) and a 78% reduction in the corresponding Ct (from ± 26.6% to ± 5.8%).

Fumigation efficiency

Efficient use of fumigants is critical to the continued viability of fumigation as a tool in SPIP management programs. Due to increasing regulatory pressures involving off-target environmental safety, often promulgated as limits on fumigant quantity and buffer zones, fumigators must achieve the greatest level of insect control with the least amount of fumigant.

Our research efforts have been targeted at developing recommendations for the optimum use of ProFume (SF), yet these fumigation profiles are applicable to all fumigants. At one structure, tarp-sealing increased the accumulated Ct by 67% with a 36% decrease in the amount of fumigant used compared to the preceding standard tape-seal fumigation. The result was the desired insect control with less fumigant, at a fumigant cost savings that more than compensated for the additional labor costs of tarp sealing. At another structure, enhanced sealing and gas introduction and equilibrium maintenance procedures resulted in a 10% increase in Ct with a 20% decrease in fumigant used, again at a fumigant cost savings that offset the additional labor costs. In addition, much of the added labor was a one-time expense for permanent sealing, the cost of which can be amortized over several fumigations.

SUMMARY

HLT values and associated Ct values may vary several-fold across areas of a single structure. Enhanced sealing procedures can increase the overall HLT, lowering the amount of fumigant necessary to achieve the desired Ct and decreasing the time necessary to introduce and equilibrate the fumigant. Planned fumigant introduction and equilibrium maintenance procedures decrease the variation in HLT resulting in more uniform Ct values across the structure, again reducing the total amount of fumigant needed. Employing these fumigation optimization techniques can improve the cost effectiveness of fumigation and help ensure the long-term availability of fumigants for pest control.