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POSSIBILITIES OF PROFUME® GAS FUMIGANT FOR THE COMMERCIAL FUMIGATION OF STORED COCOA BEANS IN EU

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ABSTRACT

Cocoa beans, shipped to EU warehouses, are stored in bulk or stack at major ports until needed for processing. They are often fumigated before transport to the processing factory to ensure disinfestation of common stored-product insects. Insect infestation usually originates in the country of production where the raw cocoa has been stored, but may also occur during transport or storage in the warehouse. Since the phase out of methyl bromide in 2000 in EU, ProFume® gas fumigant (99.8 % sulfuryl fluoride [SF]), has been seen as an alternative for methyl bromide within the commercial cocoa fumigation world. ProFume is a broad spectrum, non-ozone depleting gas fumigant developed and manufactured by Dow AgroSciences LLC. Fumigation of cocoa beans with ProFume in the United States, trial fumigations in Germany and The Netherlands and commercial fumigations in Belgium and the Netherlands have shown that fumigation with ProFume is fast and effective, without any adverse effects on the quality of the cocoa beans and their processing. The overall goal of this report was to develop experience in commercial fumigation of cocoa beans stored in stacks and in bulk.

Key words: Postharvest systems, cocoa fumigation, sulfuryl fluoride

INTRODUCTION

ProFume® gas fumigant (99.8% sulfuryl fluoride [SF]) is a broad spectrum, non-ozone depleting fumigant developed and manufactured by Dow AgroSciences LLC for the control of rodents, insects and other invertebrate pests. ProFume® was developed in response to post-harvest industry requests for an alternative to methyl bromide (MeBr). ProFume® has been registered for use in food handling establishments (e.g., pet food facilities, bakeries, food production facilities, mills, warehouses, etc.), stationary transportation vehicles (railcars, shipping containers, trucks, etc.), temporary and permanent fumigation chambers, and storage structures. ProFume® is relatively non-reactive as a gas and does not cause off-flavors. It is an odorless, colorless inorganic gas, and as such, does not form unpleasant odors. Due to its higher vapor pressure and lower sorption characteristics, ProFume® compared to MeBr penetrates commodities more effectively, reaching target pests faster for optimal control (Thoms et al., 2008). Furthermore, it has been proven that the sorption of SF is much lower than that of MeBr under identical conditions (Phillips et al., 2000).

The fumigant of choice for control of common stored-product pests during transport and storage of cocoa historically has been MeBr. However, with the adoption of the Montreal protocol, MeBr was phased out in the EU in 2000 due to its ozone depleting properties and the search for replacements and alternatives to MeBr has begun. Now, trials and experience have proven that ProFume® is a successful post-harvest fumigant for cocoa and a valuable alternative for MeBr both in efficacy and cost (Bookout and Milyo, 2006; Buckley, 2008; Adam et al., 2010). The commercial treatment of cocoa beans with ProFume® was first described in United States by Bookout and Milyo (2006), who confirmed the effectiveness, the absence of sensory effects and the customer acceptance of sulfuryl fluoride. ProFume® was granted registration for the control of stored-product insect pests in cocoa beans in EU in Belgium in 2011 and the Netherlands in 2010. In addition, after zonal re-registration under 1107/2009/EC approval for treatment of cocoa with ProFume will be also granted authorisation in Germany in the near future for cocoa bean treatment.

Cocoa (*Theobroma cacao* L.) is an internationally traded commodity with estimated annual production of over 3 million tons and a global market value of $5.1 billion (World Cocoa Foundation, 2012). Cocoa beans, shipped to EU warehouses, are stored in bulk or stacks at the major ports (Amsterdam [Netherlands], Antwerp [Belgium], and Hamburg [Germany]) until needed for processing. At arrival, they are often infested with common stored-product pests. New shipments enter the warehouses and are stored adjacent to other cocoa beans. There is no segregation of new and old shipments. As such, they are subject to re-infestation during their storage in the warehouse. Warehouse operators hold cocoa beans for numerous cocoa brokers and traders. Chocolate manufacturers typically purchase whole or partial shipments of cocoa beans from various brokers weekly. Their choice of cocoa beans depends on quality attributes, price and condition of the cocoa beans, production needs, country of origin, and other factors (Van Meijel et al., 2010; Bookout and Milyo, 2006).

In EU, cocoa fumigation can be performed in different ways: fumigation of bulk or bagged (e.g. stacked) cocoa beans in the warehouse or fumigation of bagged cocoa beans in containers. This study provides a description of the development of effective and practical methods for fumigation of cocoa on commercial scale by evaluating the current methods for fumigation with ProFume, which are acceptable to the fumigators and the cocoa industry in terms of exposure time, efficacy, costs and safety. Trial cocoa fumigations have been carried out to demonstrate that cocoa fumigation inside a warehouse can be undertaken without causing concentrations of ProFume in air that should be of concern. Additionally, current practices for fumigation with ProFume have been evaluated and adapted for fumigation of cocoa stored in stacks or bulk and gaps in knowledge on cocoa fumigation have been identified. This information is being used to establish a specific approach for the commercial fumigation of cocoa beans in EU with ProFume.

MATERIALS and METHODS

For this study, several trial fumigations in Hamburg, Germany and Amsterdam, The Netherlands have been carried out in port warehouses between 2007 and 2009. In Germany and the Netherlands, one 120 m³ stack and two 500 and 600 m³ stacks of cocoa beans were fumigated respectively. Based on these trials, commercial scale fumigation of cocoa beans (bulk stacks within the range of 3000 m³) has been evaluated.

All fumigations have been carried out according to the Dow AgroSciences' guidelines for fumigation of cocoa, now included on the national label of ProFume. According to these guidelines, cocoa in hessian bags or in bulk piles, held on a fumigant resistant foundation (e.g.

puncture-resistant tarpaulin, asphalt or concrete) have to be covered with a material resistant to fumigant penetration (such as vinyl coated nylon or polyethylene sheeting of at least 150 micron (µm) in thickness. The tarpaulin needs to be supported to create a gas expansion dome of sufficient dimensions, such as approximately 0.5 m above the items to be fumigated and at least 0.3 m around the sides, to allow gas diffusion. The edge of the tarpaulin has to be sealed by weighting the edges with sand or water 'snakes' or the equivalent.

Introduction tubes have to be directed in an open air space under the tarpaulin to avoid direct contact with the cocoa beans. Fans need to be used to mix the fumigant with the air and to aid effective penetration into the commodity. Introduction needs to be done slowly (e.g. at a rate of 0.5-2.0 kg/min) to prevent excessive cooling of air. The maximum dosage is 1500 g-h/m^3 for 48 h, with a maximum concentration of 128 g/m^3. Nonetheless, the dosage is usually reduced according to planned exposure time and temperature of the stack, as applicators follow guidelines provided by proprietary software, the ProFume Fumiguide™.

Cocoa beans can be aerated using passive or active ventilation to lower the concentration of ProFume in the fumigated area and risk zone to 3 ppm (bystanders) or 1 ppm (workers). (Initial) exclusion zone can be extended when necessary according to the instructions of the fumigation leader. Monitoring, essential for dosage accuracy and calculation of the actual half loss time (HLT), needs to be done by appropriate monitoring devices (e.g. Fumiscope[1] or SF-ReportIR[2]) as required by the Dow AgroSciences Stewardship. To confirm the concentration of ProFume, which does not exceed permissible exposure limits where workers may be present during aeration, detection devices with sufficient sensitivity need to be used such as the Interscan[3] GF-1900 or SF-ExplorIR[4].

All trial and commercial fumigations described in this study were carried out according to the safety instructions related to the use of ProFume, as described in the national label on the ProFume bottle. For evaluation of efficacy of ProFume for common stored-product insects during fumigation of cocoa, bio-assays with different target pests have been distributed within the fumigated space during the trial fumigations. During the trial fumigation in Germany, bio-assays with all life stages of Red rust flour beetle (*Tribolium castaneum* Herbst), Flat grain beetle (*Cryptolestes ferrugineus* Stephens), Merchant grain beetle (*Oryzaephilus mercator* Fauvel), Rice moth (*Corcyra cephalonica* Stainton), Indian meal moth (*Plodia interpunctella* (Hübner)) and cocoa moth (*Ephestia elutella* (Hübner)) have been evaluated. For the trial fumigation in the Netherlands, bio-assays with confused flour beetle (*Tribolium confusum* Jacquelin Du Val) were assessed.

RESULTS and DISCUSSION

Challenges have been identified based on the results of the trial fumigations of cocoa in Germany and in the Netherlands and the first commercial fumigations in Belgium and the Netherlands of both bagged and bulk cocoa beans. Based on the experiences with the trial and commercial fumigations concerning sealing of the stack, most difficulties were encountered with the sealing of the stack itself and the creation of the headspace of bulk cocoa beans. In Belgium and the Netherlands, bulk cocoa beans are stored in concrete bunkers. Gas-tight tarping of bunkers is difficult due to the large size of the beans piles, the bunker construction

[1] Trademark of Key Chemical & Equipment Co
[2] Trademark of Spectros Instruments
[3] Trademark of Interscan Corp.
[4] Trademark of Spectros Instruments

with cracks between the panels of adjacent bunkers, and the location of the bunkers (f.e. against the walls of the warehouse). Depending on the circumstances where the fumigation took place, gas tight sealing was obtained by putting a tarpaulin under the cocoa beans before loading beans in the bunker or nailing or attaching the tarpaulin to the bunker walls. For creation of the headspace above the heap or stack a tightened cable to create a kind of tent above the heap was seen to be useful.

The method of introduction of the gas is important to achieve effective and uniform gas distribution within the stack or bulk of cocoa beans. For this, different methods of introduction were evaluated: introduction at ground level under pallets of bagged cocoa beans (German trial); at the top with pulsed introduction and three fans; at the bottom; at the side (the method used in US); at ground level in the aisle between two stacks of bagged cocoa beans (Dutch trial); in the headspace or in the tubing of the recirculation system for fumigation of bulk cocoa beans (commercial fumigations). Based on these experiences, it has been shown that slow introduction from the top of the stack of cocoa beans, or in the aisle between two stacks is most effective (Van Meijel, 2010). Above this, it has been shown that despite the good penetrating properties of SF and the different methods of introduction, it is difficult to obtain a uniform distribution of SF throughout the stack or bulk cocoa beans, unless provision is made for forced circulation of the fumigant. This can be achieved by using fans or introduction in the tubing of a recirculation system. This is due to the physical properties of SF which is heavier than air and initially drops within the stack or bulk cocoa beans if active circulation is not used and the fumigant is introduced rapidly. The recirculation system that can be used for fumigation of cocoa beans is based on the US J-system, designed to avoid fumigant distribution problems in large bulk grain held in silos for the storage. This system consists of a perforated tube placed under the bulk cocoa beans before loaded into storage, while another perforate tube (if there is no large headspace possible) is placed on top of the bulk, connected with a recycling fan. It has been observed that fumigant introduction without an additional fan resulted in tarps depressed against the bulk cocoa beans due to the lower temperature of air. Dow AgroSciences recommends to introduce ProFume in the headspace above the stack or bulk cocoa beans, or in the tubing of the recirculation system. If no recirculation system is available, an additional fan can improve circulation and uniform distribution of SF within the stack or bulk cocoa beans. Based on the current experience, it is concluded that a larger headspace and a recirculation system accelerate fumigant equilibrium.

Bagged, stacked cocoa beans can be efficiently monitored using standard monitoring hoses. For bulk cocoa beans, fluctuating monitoring results were observed using standard monitoring hoses. Based on these experiences during commercial fumigations, Dow AgroSciences recommends inserting modified, perforated tubes (e.g. 1 m of PVC tube melted at one end and connected to the monitoring hoses) into bulk cocoa beans to facilitate penetration. Since the density of bulk cocoa beans is quite high, an additional pump within the monitoring system is advised.

Based on the commercial fumigations, it has been shown that a circulation system enables efficient, controlled aeration of cocoa. The circulation system can be used to ventilate fumigant from bulk cocoa beans using powerful fans. If no circulation system is available, a pre-positioned chimney, attached to a fan and venting through an opening in the roof of the warehouse, can be used to initially draw the gas out of the stack or bulk cocoa beans, followed by progressive removal of the tarpaulin.

Field trials in United States have been conducted using insect bioassays to test for optimum dosages, performance and verification that those dosages can be consistently attained and maintained. Assessments have also been made of the penetration, dispersion and

aeration characteristics of ProFume under typical conditions for commercial cocoa bean fumigations. One important outcome of the trials has been the determination that in terms of efficacy only one application rate is needed for stacks of cocoa beans fumigation under tarps (Brookout and Milyo, 2006). Tests with bio-assays with common storage pests showed that 1500 g-h/m^3controls all life stages (eggs, larvae, pupae). This was also confirmed by assessment of the bioassays distributed in the stacks during the trial fumigations in EU. However, the importance of a good equilibrium and penetration of SF in the bulk cocoa beans needs to be emphasized. As eggs are the least susceptible life stage, it is important that the dose within the bulk or stack cocoa beans is sufficient high on top as well as at the bottom. Besides that, the good equilibrium and penetration is also important to reach infestation of the sacks and the fabric of bagged cocoa beans.

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