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CURRENT STATUS OF PROFUME ® GAS FUMIGANT FOR DISINFESTATION OF COMMODITIES

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ABSTRACT

Since its first approval for fumigation of flour mills in Switzerland in 2003, ProFume® gas fumigant (99.8% sulfuryl fluoride; Dow AgroSciences LLC) has been approved for the control of stored product insects in structures (flour mills, food processing plants) and/or commodities in over 20 countries. It has been established as the fumigant of choice to replace methyl bromide to treat dried fruits and tree nuts in the United States, and cocoa beans in the United States and Northern Europe. It is also used as an effective alternative to control phosphine-resistant insects infesting grain in the United States and Australia. Ten years of studies in cooperation with six stored product research laboratories in the United States and Europe have established reliable dosages to control all stages of main stored product insects under a wide range of conditions. An extensive program of food quality studies conducted with the Dried Fruit and Tree Nut Association of California, Ege University of Turkey, Purdue University and Kansas State University in the United States, and the National Confectioners Association in the United States, confirmed that ProFume has no adverse effect on taste or quality of fumigated commodities.

Due to its fast penetration, ProFume is also an excellent wood fumigant and an effective control method for quarantine insects and nematodes in wood logs and wood packaging materials. The inclusion of ProFume in International Standard for Phytosanitary Measures (ISPM) would offer an alternative fumigant to methyl bromide to prevent the distribution of economically-important forest pests.

Key words: Commodity, grain, dried fruits, tree nuts, sulfuryl fluoride, wood, quarantine

INTRODUCTION

Sulfuryl fluoride (SF) was first marketed under trade name Vikane® (Dow AgroSciences, Indianapolis, IN) in the United States in 1961 as a structural fumigant to control wood-destroying and structure-infesting insects. In the last nine years, the use of SF, under trade name ProFume®(Dow AgroSciences, Indianapolis, IN), as a structural and commodity fumigant in the food processing industry to control stored product insects has been considerably developed around the world. The use of SF as a quarantine fumigant against undesirable forest pests globally, and as an alternative to phosphine on grain are in development.

Kenaga(1957) documented that SF was effective on a large selection of stored product insects. The study found that postembryonic stages were more susceptible to SF than the eggs were. This property of SF has been confirmed in efficacy studies conducted since (Thoms and Scheffrahn 1994, Bell et al. 1999, Baltaci et al. 2009). Outram (1967) demonstrated SF had reduced penetration through and bound to the proteinacious egg shell and embryonic membranes.

Initial research on pests of dried fruits and tree nuts was conducted by USDA-ARS in Fresno, California (Zettler et al. 1998) and Dried Fruit and Tree Nut Association (DFA) of California (Schneider and Hartsell1998). These studies established that low dosages of SF could eliminate larvae from field insects (*Cydia pomonella* (L.) and *Amyelois transitella* (Walker)) present on the crop and higher dosages would control all stages of the stored product moth *Plodia interpunctella* (Hübner). Further work demonstrated that ProFume could control all stages of closely related pyralid moth *Ephestia kuehniella* (Zeller) (Bell et al. 1999), and *Ephestia elutella* (Hübner) (Baltaci et al. 2009) with some differences of tolerances according to the age of eggs and ambient temperature.

The research conducted at DFA and Central Sciences Lab (Bell et al. 1999) was also focused on stored product beetles (*Tribolium castaneum* (Herbst) , *T. confusum* (Jacquelin du Val), *Trogoderma variabile* (Ballion), *Cryptolestes turcicus* (Grouvelle), *Ptinus tectus* (Boieldieu), *Sitophilus granarius* (L.), *Gnatocerus cornutus* (F.), *Tenebrio molitor* (L.)) and psocids *Liposcelis bostrychophila* (Badonnel) . Most species were completely controlled at all stages at cumulated dosage (CTP = Concentration x Time products) of 500 g-h/m^3 at 30°C and 1000 g-h/m^3 at 25°C. *T. castaneum* and *T. variabile* were the species needing the highest dosage to achieve complete control of the egg stage.

More research on important stored product insects was conducted with independent research institutes to confirm effective dosages on all stages of stored product moths and beetles (Thoms et al. 2008). The results confirmed that SF was effective in controlling all stages of insects with temperature ranging from 20 to 40°C without exceeding the maximum approved dosage of 1500 g-h/m^3. These research studies have been submitted and evaluated by government scientists in Europe and have resulted in approval of fumigation of mills and food processing facilities in more than 20 countries in the world. Many countries have also approved ProFume on a wide range of food commodities (Table 1).

With the increasing complexity of SF dosage in food commodity, proprietary software, the ProFume Fumiguide™, was developed by Dow AgroSciences to calculate the CTP for 19 insect pest species (Table 2) for a wide range of temperatures and exposure times. The data used to produce the Fumiguide is the result of ten years of research by six stored product research laboratories in the United States and Europe (Thoms et al. 2008), and nearly 1,200 bioassays of the key cosmopolitan stored product insects evaluated during 51 commercial fumigations (unpublished, Dow AgroSciences). When monitoring data are entered into the Fumiguide, the program will calculate the actual half loss time and accumulated dosage, predict the dosage outcome for the planned exposure period, and update instructions on exposure time (on target, shorten or lengthen) and fumigant concentration ("on target" or "add more") (Dow AgroSciences, 2005).

Table 1. Approval of ProFume gas fumigant on raw Food commodities in the world

Countries [1]	Me	USA	Be	Fr	It	Ge	Ne	Tu	Gr	Au
Cocoa		x	x			x	x			
Cereals [2]	x	x								x
Maize (Corn)	x	x								
Rice	x	x								
Bean	x									
Dried fruits [3]		x		x		x		x	x	x
Walnuts		x		x	x	x				x
Hazelnuts		x		x	x	x		x	x	x
Pistachios		x		x	x	x			x	x
Pecan		x		x	x	x			x	x
Almonds		x		x	x	x			x	x

[1] Me: Mexico; Be: Belgium; Fr: France; It : Italy; Ge: Germany; Ne: Netherland; Tu: Turkey; Gr: Greece; Au: Australia
[2] Wheat, barley, oats
[3] Raisins, apricots, figs, dates, prunes – Raisins, apricots, and figs for Turkey

Table 2. Insects currently in the ProFume Fumiguide (version 2011)

Order	Family	Name
Coleoptera (beetles)	Tenebrionidae	*Tribolium castaneum*
		Tribolium confusum
	Dermestidae	*Trogoderma variabile*
		Dermestes maculatus
	Curculionidae	*Sitophilus granarius*
		Sitophilus oryzae
	Bostrychidae	*Rhyzopertha dominica*
	Lameophloeidae	*Cryoptolestes ferrugineus*
	Chrysomelidae	*Callosobruchus maculatus*
		Acanthoscelides obtectus
	Anobiidae	*Lasioderma serricorne*
		Stegobium paniceum
	Silvanidae	*Oryzaephilus surinamensis*
Lepidoptera (moths)	Pyralidae	*Ephestia kuehniella*
		Ephestia cautella
		Ephestia elutella
		Plodia interpunctella
		Amyelois transitella
	Tortricidae	*Cydia pomonella*

EFFECTS OF SF ON QUALITY OF FOOD PRODUCTS

Many trials have been conducted to assess fumigation with SF on the quality of the commodity. Four taste tests were conducted on dried fruits and tree nuts from 1998 to 2001 to determine the potential for sulfuryl fluoride to affect the taste, in association with DFA and two groups of sensory researchers: National Food Laboratory in Dublin California and Department of Pomology, University of California, Davis. (Unpublished, Dow AgroSciences). Raisins, apricot, dates, prunes, figs, walnuts pistachios and almonds received single or multiple SF fumigations, and their taste was compared to unfumigated controls by panelists in a blind study. Results indicate that the taste, quality and commercial value of these eight commodities are not affected with treatment of SF at 2000 g-h/m^3.

Tests have also been conducted in Turkey (Fatih Şen et al. 2009) on the Sarılop fig variety. Fruit quality was evaluated after short (15 d), medium (100 d) or long-term storage (210 d). No negative impact occurred on fruit surface colour, sugaring, water content, water activity, total soluble solids, titratable acidity contents, pH and firmness following SF fumigation.

On grain, several trials were conducted at Kansas State University from 2000 to 2002 to determine the potential for SF to affect quality and nutritional characteristics of wheat grain (Unpublished, Dow AgroSciences). Wheat kernels were fumigated once or twice with SF at 2000 g-h/m^3. There was no significant difference between fumigated and nonfumigated kernels in physical/chemical characteristics (test weight, 1000 kernel weight, % ash) and nutritional quality mould infection, % fiber, % protein, % lipid, thiamin (vitamin) content). The flour made from fumigated and nonfumigated kernels did not significantly differ based on the Hagberg falling number, Alveograph and baking tests. Similarly, the quality of spaghetti (brightness, colour, cooking and tensile test) made from fumigated and nonfumigated durum wheat did not differ significantly.

In 2005, sensory evaluation of cocoa beans fumigated with SF was conducted by the National Confectioners Association (NCA) in the United States. Dried, unroasted test cocoa beans were from the Ivory Coast and Indonesia, both major sources of cocoa beans. The beans were treated with 3 SF dosages (400, 800, and 1500 g-h/m^3). Fumigated and nonfumigated cocoa beans were made into chocolate liquors and sent to nine chocolate manufacturers for sensory evaluation. The NCA members concluded that there was no significant adverse effect on the sensory properties of liquors made from SF treated beans, and subsequently adopted SF for cocoa beans fumigation.

Its successful commercial use in many countries of Europe and America prove that ProFume is a technically and economically viable alternative to methyl bromide for commodity fumigation.

CURRENT DEVELOPMENT FOR SF

Currently, high levels of phosphine resistance in the flat grain borer, Cryptolestes ferrugineus, are resulting in control failures for phosphine treatment of central grain storages in Australia. Sulfuryl fluoride and phosphine have different modes of action (Thoms and Phillips 2004), phosphine resistant insects are not cross-resistant to sulfuryl fluoride (Bell et al. 2002), and there is no known insect resistance to sulfuryl fluoride (Thoms and Phillips 2004). These characteristics make ProFume a primary candidate for rotating with phosphine to combat resistance. In cooperation with government researchers and commercial bulk grain handlers in Australia, Dow AgroSciences is evaluating the practicality and effectiveness of SF

fumigation for typical Australian grain storage bunkers. The effectiveness of low SF concentration for long exposure times (10-14 d) in bunkers is a new area of research since previous research with SF on stored product insects was conducted for shorter exposure times, typically 24-48h.

It has been demonstrated that SF is effective in controlling a wide range of insects infesting unseasoned wood, such as Asian long horn beetle *Anoplophora glabripennis* (Motschulsky) (Barak et al. 2006), Bamboo borer *Chlorophorus annularis* F.(Daojian et al. 2010), Emerald ash borer *Agrilus planipennis* (Fairmaire) **(**Barak et al. 2010) and various species of Cerambycidae, Scolytidae, and Platypodidae (Soma et al.1996, Mizobuti et al. 1996). Studies by leading nematologists and quarantine experts have shown effective control of pine wood nematode *Bursaphelenchus xylophilus* (Steiner & Buhrer) (Soma et al. 2001, Dwinell et al. 2005; Flack et al. 2008 unpublished; Sousa et al. 2010.

The only current approved treatments for wood packaging in ISPM N°15 (International Standard for Phytosanitary Measures) are heat and methyl bromide (MB). Heat can damage commodities and their packaging. MB has been phased out in many areas in the world, even for use in quarantine and preshipment treatments which are excluded from the Montreal protocol. Therefore, it is critical that an alternative fumigant is approved in international trade for treatment of wood packaging fumigation, and Dow AgroSciences is pursuing research with ProFume to obtain inclusion of SF in ISPM N° 15. ®Trademark of Dow AgroSciences LLC

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