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Efficacy of sulfuryl fluoride against major insect pests of stored commodities in Indonesia

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ABSTRACT

In Indonesia, there are lack of data on sulfuryl fluoride efficacy against major insects pest of stored commodities. Efficacy test of sulfuryl fluoride against *Sitophilus zeamais* Motschulsky on milled-rice (*Oryza sativa* L.), *Tribolium castaneum* (Herbst) on maize (*Zea mays* L.), *Cryptolestes* sp. on wheat (*Triticum aestivum* L.) flour, and *Lasioderma serricorne* Fabricius on tobacco (*Nicotiana* sp.) was conducted at the dosages of 36, 48, 72, and 92 gm^{-3} for 24 h and showed 100% mortality of these insects. Seven days incubation of culture media after fumigation showed that in all dosages of fumigant treatments, i.e. 36, 48, 72, and 96 gm^{-3}, there were no indication of any emerged larvae, except in the treatment using *T. castaneum* on maize at the dosages of 36 and 48 g m^{-3}, which showed 11 and 2 larvae respectively.

Key words: Emerged larvae, Fumigation, Mortality, Stored commodities, Test insects

The main problem when we store commodities is insect pests which economically cause quantity and quality losses. The preferred method for controlling insects pests in the storage and its facilities is fumigation. Since methyl bromide was discontinued for commodity maintenance in storage, phosphine and sulfuryl fluoride taken over this important role. Ease of application, effectiveness against all respiring pest species and non-toxic residues have made phosphine as the main choice of fumigant (Chaudhry, 2000). However, phosphine needs a much longer exposure time than methyl bromide for full effectiveness. Besides, phosphine is corrosive and cannot be applied to commodities with high moisture content (m.c.). Sulfuryl fluoride has properties similar to methyl bromide such as effectiveness at quite short exposure times and can be applied to commodities with high m.c., but unlike methyl bromide, sulfuryl fluoride is not an ozone depleting substance. Therefore, sulfuryl fluoride has great potential to replace methyl bromide.

Sulfuryl fluoride has been used as structural fumigant including their contents in the USA since 1959 (USEPA, 1993), particularly against drywood termites, and for fumigation of post-harvest products (i.e. tree nuts, dried fruits, cereal grain storage, milling and processing) since 2004 (Prabhakaran, 2006). Efficacy of sulfuryl fluoride on mixed age cultures of *Lasioderma serricorne* Fabricius, *Oryzaephilus surinamensis* L., *Rhyzopertha dominica* Fabricius, *Sitophilus oryzae* L., *Tribolium castaneum* Herbst, *Trogoderma granarium* Everts and eggs of *Ephestia cautella* Walker showed that 100% mortality of *T. granarium* and *Rhyzopertha dominica* occurred at 10 mg/L for 24 h, while the mortality of *L. serricorne, T. castaneum* and *E. cautella* at a dosage of 40 g m^{-3} for 24 h were 99.6, 98.1 and 92.7% respectively (Sriranjini and Rajendran, 2008). Sulfuryl fluoride also has potential for controlling two major New Zealand forest insect pests and eight fungi – adult *Arhopalus*

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tristis Mulsant (15 g m^{-3}) and its eggs (120 g m^{-3}), both adult and larvae of *Hylastes ater* Paykull (15 g m^{-3}) and eight fungi (30 g m^{-3}) (Zang, 2006).

In Indonesia, sulfuryl fluoride has been recommended as an alternative to methyl bromide and it was first registered as Fumiguard 99 GA in 2010 to control insect pests in feed storage and milled rice (*Oryza sativa* L.). There is lack of data on sulfuryl fluoride efficacy against major insect pests of stored commodities. Recenly, the second product of sulfuryl fluoride, Indofum 99 GA, has been tested for its efficacy for registration purposes. The objective of this field efficacy test was to evaluate the effectiveness of Indofum 99 GA (sulfuryl fluoride 99%) against *Sitophilus zeamais* Motschulsky on milled rice, *T. castaneum* on maize (*Zea mays* L.), *Cryptolestes* sp. on wheat (*Triticum aestivum* L.) flour, and *L. serricorne* (Fabricius) on tobacco (*Nicotiana* sp.) for registration purposes.

MATERIALS AND METHODS

Sulfuryl fluoride efficacy tests were conducted in March 2016 at SEAMEO BIOTROP's facilities in Bogor, Indonesia. Fumigation was conducted at Postharvest Research Warehouse, whereas for the preparation of the test insects, observation of insects mortality and number of insects spawns were conducted at the Entomology Laboratory.

The average temperature and r.h. inside the warehouse during the fumigation period were 26.6°C and 84.1% respectively.

Preparation of test insects

The insects used for efficacy test were adults of *T. castaneum, S. zeamais*, *Cryptolestes* sp. and *L. serricorne* and their eggs. Insects used for the test were obtained from the insect culture collection of the Entomology Laboratory of SEAMEO BIOTROP. *Tribolium castaneum* was reared on wheat flour + dried yeast (2%), *S. zeamais* on milled rice, *Cryptolestes* sp. on broken maize and *L. serricorne* on Quaker oats (*Avena sativa* L.) + dried yeast (2%).

Fifty test insects were prepared in a beaker glass with suitable culture media for each insect species. Each beaker glass containing culture media and test insects was covered with gauze to allow the fumigant gas to penetrate into the beaker glass. Adults of each test insect group had been incubated in the culture media for one week before fumigation treatment. It was expected that the eggs from each adult of test insects would be present in the media. The eggs that were laid by adults were also used for fumigation test.

The sulfuryl fluoride used in this study was Indofum 99 GA, supplied by Indo Global Trade Company. Indofum 99 GA used in this test was cylinderized sulfuryl fluoride weighing 20 kg. Efficacy test of Indofum 99 GA was performed using completely randomized design, consisted of five treatments, i.e. four dosages of Indofum 99 GA (36, 48, 72 and 96 g m^{-3}) and control (without fumigant), with five replicates.

Fumigation

Fumigation chambers made of PVC pipe framework (1 m × 1 m × 1 m) were arranged in the warehouse based on the layout of the experiment. A plastic jar containing1 kg sample of commodities were placed in the centre of the chamber. The sample of commodities were wheat flour for *Cryptolestes* sp., maize for *T. castaneum,* milled rice for *S. zeamais* and tobacco for *L. serricorne.* The top of the plastic jar was left open and each test insect culture that had been prepared in a beaker glass was subsequently put in the top of the plastic jar containing the related commodities.

Plastic hose for distributing sulfuryl fluoride gas was mounted in the centre of the chamber. The PVC cover sheets (thickness 150 µm) were used to cover fumigation chamber. The edges of plastic cover sheets were sealed with sand snakes to avoid gas leakage. Indofum 99 GA cylinder was placed on top of a digital weighing scale with the capacity of 100 kg. Fumigation was conducted by flowing the sulfuryl fluoride gas from the cylinder into the chamber through the distribution hose in accordance with each treatment dosage. The control chambers were not treated by sulfuryl fluoride, but only covered with PVC cover sheets. Fumigation was conducted for 24 h and terminated by aerating the enclosure until the sulfuryl fluoride concentration reached the threshold limit value (TLV), then the plastic cover sheets were removed.

Parameters observed were mortality of test insects and the number of larvae that emerged from the eggs 7 days after fumigation was terminated. Sulfuryl fluoride gas was checked at 1 h and 24 h after fumigation started using RIKEN Model FI-21 TYPE-53. After fumigation was terminated, the adult of each test insects were removed from the test media in the beaker glass for mortality observation. Beakers glass containing culture media were then incubated for 7 d. After 7 d of incubation, number of eggs emerged into larvae on each culture media were observed and calculated. The number of larvae found in the culture media was counted after 7 d of incubation and carried out under microscope, because the larvae were very small. Mortality data were analyzed using analysis of variance (ANOVA) continued with DMRT at 5% significance level were performed to determine their efficacy.

RESULTS AND DISCUSSION

Efficacy of sulfuryl fluoride against adult stage

The results of exposing 50 adults of each insect to sulfuryl fluoride at the dosages of 36, 48, 72, and 92 g m^{-3} for 24 h showed that 100% mortality occurred for all of insects tested. There were no dead test insects found in the control. It means that all dosages treatment of sulfuryl fluoride were effective in controlling adults stage of *S. zeamais*, *T. castaneum*, *Cryptolestes* sp. and *L. serricorne* with exposure time of 24 h (Table 1).

Efficacy of sulfuryl fluoride against egg stage

Effectiveness of sulfuryl fluoride against egg stage was assessed from the emerged larvae found in the culture media after 7 days of incubation. In determining the effectiveness of a fumigant against egg stage, the initial number of eggs used were unknown. However, it is assumed that all the adults laid their egg during pre-treatment incubation.

The number of live larvae found in the culture media after 7 days of incubation is shown in Table 2. The incubation of culture media results showed that in all dosages of fumigant treatments, i.e. 36, 48, 72, and 96 g m^{-3}, there were no indication of any larvae found, except in the treatment using *T. castaneum* on maize at the dosages of 36 and 48 g m^{-3}.The number of live larvae on dosages of 36 and 48 g m^{-3}were 11 and 2 larvae respectively. Meanwhile, the number of live larvae found in control culture media of *S. zeamais* (milled rice), *T. castaneum* (maize), *Cryptolestes* sp. (wheat flour) and *L. serricorne* (tobacco) were 85, 206, 293, 720, and 95 larvae respectively. The absence of larvae in almost all treatments, except treatment on dosages of 36 and 48 g m^{-3}, indicated that the eggs in culture media being exposed to sulfuryl fluoride did not hatch.

All dosages of sulfuryl fluoride used in this research were effective against adult and egg stage of *S. zeamais* on milled rice, *Cryptolestes* sp. on wheat flour, *L. serricorne* on tobacco and adult stage of *T. castaneum* on maize with 24 h exposure time. Complete mortality (100%) of egg stage of *T. castaneum* on maize was achieved in dosage of 72 and 96 g m^{-3}, although the number of live larvae found as egg survivour in the dosage of 48 g m^{-3}were only 2 larvae (Tables 1, 2). This indicated that the eggs of *T. castaneum* have higher tolerance to sulfuryl fluoride compared

Table 1 Efficacy of sulfuryl fluoride against adults stage of *Sitophilus zeamais, Tribolium castaneum, Cryptolestes* sp. and *Lasioderma serricorne* after 24 h exposure

Dosage (g m^{-3})	Corrected mortality of test insects (%)*)			
	S. zeamais on milled rice	*T. castaneum* on maize	*Cryptolestes* sp. on wheat flour	*L. serricorne* on tobacco
0 (control)	0 b	0 b	0 b	0 b
36	100 a	100 a	100 a	100 a
48	100 a	100 a	100 a	100 a
72	100 a	100 a	100 a	100 a
96	100 a	100 a	100 a	100 a

*Value at the same column followed by the same letter is not significantly different based on Duncan MRT at $P < 5\%$

Table 2 Efficacy of sulfuryl fluoride against egg stage of *Sitophilus zeamais, Tribolium castaneum, Cryptolestes* sp. and *Lasioderma serricorne* after 24 h exposure

Dosage (g m^{-3})	Number of larvae found after fumigation			
	S. zeamais on milled-rice	*T. castaneum* on maize	*Cryptolestes* sp. on wheat flour	*L. serricorne* on tobacco
0 (control)	85	293	720	95
36	0	11	0	0
48	0	2	0	0
72	0	0	0	0
96	0	0	0	0

with adult and egg stage of *S. zeamais, Cryptolestes* sp. and *L. serricorne*. Another study indicated that *T. castaneum* eggs require higher dosage (48.2 g m^{-3}) to achieve 100% mortality with exposure time of 48 h compared to the adult, larvae, and pupae stages (Jagadeesan et al., 2014). Bell et al. (2003) also showed that the eggs of *T. castaneum* is the most tolerant to sulfuryl fluoride compared to egg and post-embryonic stages of *Tenebrio molitor* L., *Ephestia kuehniella* Zeller, *T. confusum* Jacquelin du Val, *S. granarius* L. and *Liposcellis bostrichophila* Badonnel.

Low rate of egg respiration and impermeability of egg chorion caused low level of sulfuryl fluoride uptake and caused the eggs to be more tolerant to fumigant (Outram, 1967a,b). Enhancing the effectiveness of sulfuryl fluoride can be done by increasing the duration of exposure and increasing the temperature (Bell and Savvidou, 1999). Temperature during fumigation played an important role in *T. castaneum* eggs but not in adult stage. Research at flour mills showed that egg mortality was about 80% when mill temperature was below 25°C, but when the temperature dropped below 23°C, the mortality of egg decreased about 10% (Lawrence et al., 2012).

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