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Mixed fumigation of sulfuryl fluoride and carbon dioxide to tobacco lamina

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Abstract

Tobacco lamina is often damaged by stored product insect pests during storage and processing. Currently, phosphine fumigation is widely used to control the pests, however, its application has been restricted due to its high toxic, flammable, explosive, and corrosive to metals. Sulfuryl fluoride is favored by tobacco factories because of its wide lethal effect to different species of insect pests, high diffusivity, permeability, low toxicity, low residue, and no corrosive to metals. To improve the safety and lethal effect of sulfuryl fluoride, the mixed fumigation of sulfuryl fluoride and carbon dioxide (weight ratio 7:3) was studied. Results showed that all of the eggs, larvae, pupae and adults of *Lasioderma serricorne* at 30 g/m^3 of the mixture were dead after being treated at 28±2°C, 60±5% RH for 4 d（Ct value 2880 g.h/m^3). The mixture treatment with different concentrations had no significant effect on the chemical composition of tobacco lamina, and only the total plant alkaloid was slightly decreased. The sensory quality of tobacco lamina did not change, and the residue was not significantly increased. The mixed fumigation can reduce the use of sulfuryl fluoride and improve the safety during tobacco storage, which is significant for the ecological control of stored tobacco pests and the reduction of environmental pollution.

Keywords: Sulfuryl fluoride, Carbon dioxide, Mixed fumigation, Tobacco lamina, *Lasioderma serricorne*

Introduction

Lasioderma serricorne is one of the most destructive insect pests to stored tobacco leaves and cigarettes (Edde, 2019). Phosphine fumigation is the most widely used chemical control method by various tobacco processing factories during tobacco storage (Zhu et al., 1995). However, its application is restricted to certain predetermined conditions due to its high toxicity, flammability, explosiveness, and corrosivity to metals. Sulfuryl fluoride is favored by tobacco factories and has

a broad application due to its high diffusivity, permeability, low toxicity, low residue, and non-corrosivity to metals. Research has shown that carbon dioxide can enhance the penetrability of phosphine, which makes phosphine uniformly distributed in the enclosure. In addition, carbon dioxide can stimulate the insect respiration, hence enhancing the lethal effect on insects (Jian et al., 1995). To improve the fumigation effectiveness, shorten fumigation time, and reduce sulfuryl fluoride deflagration risk, mixture of sulfuryl fluoride and carbon dioxide was used to control tobacco insects during tobacco storage. Relationships among exposure time, concentration of sulfuryl fluoride and carbon dioxide, and mortality of Lasioderma serricorne were determined in this study which provided the basic information for the determination of dose of sulfuryl fluoride and carbon dioxide, and exposure time for the mixed fumigation.

Materials and methods

Insects

Lasioderma serricorne was collected from a tobacco factory located at Zhengzhou, Henan, China, and reared on a diet of 45% flour, 5% yeast and 50% wheat kernels in weight. Pupae of *Lasioderma serricorne* were obtained from the culture. The 2 d old eggs of *L. serricorne* were provided by the Henan University of Technology, Henan, China.

Treatments

Sulfuryl fluoride and carbon dioxide were provided by Shanxi Xinjinye Tobacco Technology Co., China. The weight ratio of sulfuryl fluoride and carbon dioxide was 7:3 and the concentration of the mixture was 30 g/m^3. The exposure time was 48, 72, 96, and 120 h. There were three replicates for each treatment.

Each pile with 12 tobacco stacks were sealed with polyethylene film and adhesive tape. The volume of a pile was about 60 m^3. During treatment, temperature and relative humidity were maintained at 28±2°C and 60±5%, respectively. One hundred each stage (egg, larva, pupa, and adult) of *L. serricorne* were introduced into a glass vial filled with tobacco leaves, and the glass vial was covered by 200 mesh screen.

Placement of air sampling tube

To install the air sampling tube, one cigarette box at the center of each stack was selected. One plastic tube was inserted into the center of the cigarette box through a premade hole, and the tube was fixed by adhesive tape. The gas sampling tube was also fixed at the outside of the tobacco pile. The concentration of sulfuryl fluoride in the cigarette box was measured every 0.5 h up to 12 h at beginning of the treatment, and then every 2 h up to the end of the treatment.

Determination of insect mortality

After the polyethylene film which sealed the tobacco pile was removed, the glass vials holding the treated insects and tobacco leaves were removed and the insects were transferred to petri dishes. The survival of the insects (larvae, pupae, and adults) in the petri dishes was observed. The eggs in the petri dishes were incubated at 30°C and 70% RH for 14 d.

Results and discussion

Effect of the mixture on insect mortality

As shown in Table 1, the longer the treatment time, the higher the mortality for any stage of the insect. Eggs, larvae, pupae, and adults were dead at 96 h.

Table 1. Effect of the mixture on insect mortality

Exposure time (h)	Mortality (mean ± standard deviation)			
	Adult	Larva	Pupa	Egg
48	100±0	90±2.5	100±0	85±4.5
72	100±0	98±1.5	100±0	96±3.5
96	100±0	100±0	100±0	100±0
120	100±0	100±0	100±0	100±0
Control	15±3	0±0	0±0	37±6.5

Effect of the mixture on chemical composition of tobacco lamina

The effect of the mixture on the chemical composition of tobacco lamina is shown in Table 2. The mixture had no obvious effect on the chemical composition of the tobacco lamina. Compared with the control, the concentrations of total nitrogen, reducing sugar, potassium, chlorine, total volatile acid, and total volatile base did not change, while the total alkaloid decreased slightly.

Table 2. Effect of the mixture on chemical composition of tobacco lamina

Exposure time (h)	Total alkaloid (%)	Total nitrogen (%)	Reducing sugar (%)	Potassium (%)	Chlorine (%)	Volatile acid (%)	Volatile base (%)
48	3.03	2.01	21.96	1.70	0.32	0.175	0.191
72	3.05	2.03	22.17	1.74	0.31	0.173	0.188
96	3.10	2.02	22.38	1.69	0.33	0.176	0.182
120	3.24	2.00	23.68	1.65	0.30	0.175	0.190
Control	3.23	2.01	22.55	1.69	0.31	0.174	0.190

Effect of the mixture on sensory quality of tobacco lamina

The sensory quality after the 120-h treatment was better than the control, while the sucking quality after 48, 72 and 96 h treatments were equivalent to that of the control. After the mixture treatment, the sensory quality of tobacco lamina had no adverse effect.

Table 3. Effect of the mixture on sensory quality of tobacco lamina

Exposure time (h)	Aromatic quality	Amount of aroma	Con[a]	Mis[a]	Ene[a]	Irr[a]	Aft[a]	Quality Grade
48	6.5	6.5	6.0	6.0	6.5	6.0	6.5	6.5
72	6.0	6.5	6.0	6.0	6.5	6.0	6.5	6.5
96	6.0	6.5	6.0	6.0	6.5	6.0	6.5	6.5
120	6.0	6.5	6.0	6.0	6.5	6.0	6.0	6.0
Control	6.0	6.5	6.0	6.0	6.5	6.0	6.5	6.5

[a]Con = Concentration, Mis = Miscellaneous gas, Ene = Energy, Irr = Irritability, Aft = Aftertaste

Effect of the mixture on fluorine residue

With the increase of the dosage of sulfuryl fluoride or the exposure time, the residue of fluoride in the tobacco lamina increased. Compared with the control, the fluoride residue increased by 3.1 mg/kg at 30 g/m^3 of the mixture concentration and 4 d treatment (Table 4).

Table 4. Effect of the mixture on fluorine residue

Exposure time (h)	48	72	96	120	Control
Residue (mg/kg)	26.8	27.7	31.0	31.0	27.9

Discussion and conclusions

At 28 ± 2°C and 60 ± 5% RH, all insect stages (eggs, larvae, pupae, and adults) were dead under the mixture concentration of 30 g/m^3 and 4 d treatment, which had a Ct product of 2880 g·h/cm^3. The mixture treatment with different concentrations did not significantly influence the chemical composition of tobacco lamina, and only the total alkaloid was slightly decreased. After the fumigation, the sensory quality of tobacco lamina did not change, and the residue was not increased significantly.

The mixed fumigation of sulfuryl fluoride and carbon dioxide requires a higher airtightness level of the treated enclosures. In practice, when mixed fumigation is applied, the airtightness of the enclosure must be inspected carefully. If the airtightness of enclosure cannot meet the requirement, the amount of sulfuryl fluoride must be increased to compromise the less sealing level. Otherwise, the fumigation time should be increased.

References

Edde PA (2019) Biology, ecology, and control of *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae): A review. J Econ Entomol **112**: 1011-1031.

Zhu SM, Teng JF, Pan GY, Zhang J, Hu SP (1995) Mixed fumigation of PH_3 and CO_2. Grain Oil Storage Sci Tech Comm (Chinese) **4**: 25-28.

Jian F, Chen QZ, Lu AB (1995) Some biochemical aspects of phosphine in combination with carbon dioxide against the adults of *Tyrophagus putrescentia* (Schrank)(Astigmata: Acaridae). Acta Entomologica Sinica (Chinese) **38**: 13-19.