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PENETRATION CAPACITY OF VAPORMATE^{TM} INTO COMMERCIALLY PLASTIC WRAPPED CARDBOARD BOXES FILLED WITH SULTANAS FOR CONTROLLING STORED PRODUCT PESTS

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ABSTRACT

Stored product pests are a serious threat to the grains and dried fruit industry. These pests damage the produce and reduce the commercial value. Dried fruit is often packaged in smaller cardboard containers and then shrink wrapped. This packaging can be difficult to treat while many traditional fumigants also leave residues that require significant ventilation, with holding periods and residue testing. The study was conducted using 5 types of multilayer cardboard boxes wrapped with plastic sheet containing sultanas placed inside a fumigation tent. Mixed culture of saw toothed grain beetle (*Oryzaephilus surinamensis* L.) and red flour beetle (*Tribolium castaneum* (Herbst) were placed inside packed commodities and treated with Vapormate^{TM} at 420 g m-3 at or above 15 ^{0}C for 24 h. Sampling lines were placed in each packed box and the gas samples were taken at regular time intervals to monitor the penetration capacity of Vapormate^{TM} through out the treatment period. The study found that Vapormate^{TM} penetrated into the multilayered cardboard wrapped with plastic sheet, providing complete mortality of both adult and immature stages of stored product pests. Vapormate^{TM} is an effective fumigant alternative to methyl bromide and other fumigants while being a fumigant that can be managed safely as a result of its relatively high TLV. Vapormate^{TM} could also be used as a phosphine resistance breaker in countries where resistance exists. The dried fruit and grains industries will benefit from an alternative fumigant that penetrate effectively into the packed commodities and controls all life stages of stored product pests

Key Words: stored product insects, dried fruits, ethyl formate, fumigation, generally regarded as safe, methyl bromide alternative, phosphine resistance

INTRODUCTION

Ethyl formate is a fast acting, flammable liquid that has been traditionally used for fumigation of dried fruit since 1927 (Simmons and Fisher, 1945) for controlling stored product insects (Hilton and Banks, 1997). Ethyl formate and its break down compounds are naturally present in food commodities (Desmarchelier, 1999) and have Generally Recognised as Safe (GRAS) status (US FDA, 1984). Ethyl formate has low mammalian toxicity. Vapormate^{TM} contains 16.7 % (by weight) of ethyl formate in liquid carbon dioxide (10.7 % by volume of ethyl formate in gaseous carbon dioxide). The addition of carbon dioxide enhances the toxicity of ethyl formate towards the target pests. Studies have shown that Vapormate^{TM} has been effective in controlling adult and immature stages of storage pest of cereal grains, dried fruits

and nuts. These studies have been conducted by exposing the stored pests directly to the fumigant (Krishna et al., 2002). However in commercial situation, insects are concealed between the food commodities and are unlikely to directly expose to Vapormate^{TM}. For example, sultanas are packed in plastic card board boxes placed inside the tent and treated with Vapormate^{TM}. In this situation, Vapormate^{TM} should penetrate into the cardboard boxes and kill the target pest before transporting to local or overseas markets. Therefore this study has been designed to determine if the registered target dose rate (420 g m-3 for 24 h) penetrates through cardboard boxes and achieves complete control of immature and adult stages of saw toothed grain beetle (*Oryzaephilus surinamensis* L.) and rust red flour beetle (*Tribolium castaneum* (Herbst).

MATERIALS AND METHODS

Fumigation was conducted in a tent to reflect the current practice followed by the customer. The internal volume of the tent was 38 m^3.The loading factor was 68 %. The tent was made of a tarpaulin that was secured with the ground using a sand snake to prevent the leakage. Sultanas were packed in a range of boxes used for commercial sales as shown below in Table 1. Some boxes were tightly warped with polythene sheet.

Table 1. Dried fruits stored in different type of boxes used for Vapormate^{TM} fumigation

No.	Pack Format	Pack Weight (kg)	Packs / Layer	No. Layers	Total Packs	Total Weight (kg)	Carton Type	Wrap
1	Bulk Australian - 4 Crown	12.5	12	7	84	1050	2 Piece	Solid
2	Wooden Pallet Bins	400	1	3	3	1200	Open box	Open
3	Bulk Australian - 3 Crown	12.5	12	7	84	1050	2 Piece	Perforated
4	Import (Plain Carton)	12.5	12	7	84	1050	1 Piece	Solid
5	Multi Packs	5.76	16	8	128	737.28	1 Piece	Solid

STORED PRODUCT INSECTS

Both adult and immature stages of saw toothed grain beetle *O. surinamensis* and rust red flour beetle *T. castaneum* were placed inside a livestock tube (100 mm x 25 mm). The open end of the livestock tube was covered with sieve plastic lid to allow the gas to pass through and prevent the insects escaping during the trial. The control insects were used and not treated with Vapormate^{TM}.

FUMIGATION

Cardboard and wooden boxes containing dried fruits were loaded into the tent. The livestock tube containing target pests were marked and randomly placed in some of the boxes and tent. The recommended product (15.60 kg, 420 g m-3) was applied using a vaporiser into the tent.

The Vapormate™ level inside the tent and the cardboard box was measured using a portable monitoring device. At the end of the fumigation period (24 h), the remaining fumigant was safely vented into the atmosphere. G460 Multigas monitor was used to measure ethyl formate and carbon dioxide. Gas samples were collected from the tent and sampling boxes. Each sampling line was colour coded to avoid confusion (Table 2). The sampling lines were placed deep into the box.

Table 2. Penetration of ethyl formate and carbon dioxide into the box

Number	Sampling location	Sample Line colour	Ethyl formate (g/m^3)*#	Carbon dioxide (g/m^3)*#
1	In the tent- Back Middle	Yellow black	24.58a	189.03ab
2	In the tent- Middle-top	Green black	24.78a	189.49ab
3	In the tent- Font-Bottom	Blue black	25.32a	190.40ab
4	Sample 1	Green	15.37bc	157.91b
5	Sample 2	Blue	24.08ab	188.80ab
6	Sample 3	White	17.80ab	218.32a
7	Sample 4	Yellow	6.24c	147.98b
8	Sample 5	Blue/White	18.30b	170.49b

*Values followed by the same letter within a column are not significantly different ($P \leq 0.05$). # Mean of ethyl formate and carbon dioxide levels for 24 h

MORTALITY ASSESSMENT

After fumigation treatment, the live stock tube containing the target pests were assessed for mortality. The adult mortality was assessed 24 h after treatment, removed and the remaining mixed age cultures incubated between 20 and 25 ^{0}C. Subsequent emerging adults were counted 7, 14 and 28 d after treatment. Control adults and immature insects were assessed at the same assessment dates.

STATISTICAL ANALYSIS

The levels of ethyl formate and carbon dioxide found inside the tent and different boxes was analysed using a one way ANOVA followed by a test for Fishers least significant differences The analyses were conducted using MINTAB version 15.

RESULTS AND DISCUSSION

During Vapormate™ treatment, the required temperature (above 15 ^{0}C) was maintained for 24 h inside the Vapormate™ treated tent. The recommended dose rate was applied into the tarp (420 g m-3) and at the end of the fumigation period (24 hours), the tarpaulin sides were opened and the ventilation fan was switched on for 1 hour. After ventilation, ethyl formate (<100 ppm) and carbon dioxide (<5000 ppm) levels were below the safe level and the boxes were safely unloaded. There were no significant difference between the level of ethyl formate

found in the tent compared with sample 2 (wooden pallet bins) and sample 3(Bulk Australian - 3 crown) however the level found in sample 1 (Bulk 4 crown-solid wrap) sample 4 (Import plain carton solid) and sample 5 (multipacks solid) was significantly different to the level found in the tent (Table 2). This is not surprising as sample 2 was not plastic wrapped and sample 3 had perforation therefore the penetration and ethyl formate level would be higher than the tightly wrapped samples. Ethyl formate penetrated into the tightly wrapped boxes but the levels of penetration varied in sample 1, 4 and 5(Table 2).

All the adult insects placed at various locations within the tent and boxes were killed 24 h after treatment. Only 3 adults of *O. surinamensis* and 2 of *T. castaneum* were killed in control treatment. No adults were emerged from the mixed culture 7, 14 and 28 d after Vapormate™ treatment whereas there were emergences from the control treatment (Table 3). Complete mortality of adults and mixed age culture of *O. surinamensis* and *T. castaneum* placed inside the various boxes reflects the fact that the dose rate used for the trial penetrated deep into the plastic wrapped dried fruit box and provided 100 % control. Previous studies conducted in 20ft shipping container loaded with unprocessed sultanas with 34 g m-3 of ethyl formate for 48 h treatment period (206 g m-3 of Vapormate™) provided 100 % mortality of mixed population of the stored product pests *T. confusum* and *P. interpunctella* (Tarri et al., 2007). Although the treatment time was longer the dose rate was half compared with our study (420 g m-3 for 24 h).

Table 3. Insects emerging from livestock after treatment with 480 g/m^3 Vapormate™ for 24 h

Insects species	Vapormate™ treatment	24 h after treatment		Mortality (in %)	7 days after treatment Number of adults emerging	14 days after treatment Number of adults emerging	28 days after treatment Number of adults emerging
Saw toothed grain beetle		Live	Dead				
O. surinamensis	Sample box-1	0	112	100.00	0	0	0
	Sample box-4	0	193	100.00	0	0	0
	Sample box-5	0	201	100.00	0	0	0
	In the tent	0	242	100.00	0	0	0
	Control	212	3	1.42	16	12	13
Red rust flour beetle							
T. castaneum	Sample box-2	0	81	100.00	0	0	0
	Sample box-3	0	94	100.00	0	0	0
	In the tent	0	74	100.00	0	0	0
	In the tent	0	76	100.00	0	0	0
	Control	112	2	1.79	14	16	6

This study demonstrates that Vapormate™ @ 420 g m-3 for 24 h treatment penetrates into the multilayer cardboard plastic wrapped boxes and provide complete control of the target insect species tested. Based on this result, Vapormate™ is a potential replacement fumigant for methyl bromide application in dried fruits.

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